Notice No.4

Rules and Regulations for the Classification of Naval Ships, January 2018

The status of this Rule set is amended as shown and is now to be read in conjunction with this and prior Notices. Any corrigenda included in the Notice are effective immediately.

Please note that corrigenda amends to paragraphs, Tables and Figures are not shown in their entirety.

Issue date: June 2018

Amendments to	Effective date	IACS/IMO implementation (if applicable)
Volume 2, Part 1, Chapter 3, Sections 4 & 17	1 July 2018	N/A
Volume 2, Part 2, Chapter 1, Sections 1 to 13	1 July 2018	N/A
Volume 2, Part 9, Chapter 1, Section 1	1 July 2018	N/A
Volume 2, Part 9, Chapter 3, Sections 6 & 8	1 July 2018	N/A
Volume 2, Part 9, Chapter 6, Section 4	1 July 2018	N/A
Volume 2, Part 9, Chapter 7, Sections 2 & 3	1 July 2018	N/A
Volume 2, Part 10, Chapter 1, Section 7	1 July 2018	N/A

Lloyd's Register

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Volume 2, Part 1, Chapter 3
Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems

■ *Section 4*
Operating conditions

4.8 Astern power

4.8.1 ~~Sufficient astern power is to be provided to maintain control of the ship in all normal circumstances~~ In order to maintain sufficient manoeuvrability and secure control of the ship in all normal circumstances, the propulsion machinery is to be capable of reversing the direction of thrust so as to bring the ship to rest.

~~4.8.2 Engine builders are to satisfy the Surveyors by tests on individual engines that the requirements in *Vol 2, Pt 1, Ch 3, 4.7 Power conditions for generator sets 4.7.1*, as applicable, can be complied with, due account being taken of the difference between the temperatures under test conditions and those referred to in *Vol 2, Pt 1, Ch 3, 4.4 Ambient reference conditions 4.4.1*. Alternatively, where it is not practicable to test the engine/generator set as a unit, type tests (e.g. against a brake) representing a particular size and range of engines may be accepted. With engines and gas turbines any fuel stop fitted is to be set to permit the short period overload power of not less than 10 per cent above full rated output (kW) being developed.~~

4.8.2 The propulsion machinery is to be capable of maintaining continuous astern power for the maximum astern speed and time specified by the Owner.

4.8.3 Where appropriate the propulsion machinery is to be capable of achieving the astern power necessary to meet the requirements of the **LMA** or **LMNA** notation as applicable (*see Vol 3, Pt 1, Ch 4 Manoeuvring Assessment*).

■ *Section 17*
Sea trials

17.2 Programme

17.2.2 Main propulsion systems are to undergo tests to demonstrate the astern response characteristics. The tests are to be carried out over at least the manoeuvring range of the propulsion system and from all control positions. A test plan is to be provided by the yard and accepted by the Surveyor. If specific operational characteristics have been defined by the manufacturer, then these are to be included in the test plan.

17.3 Performance testing requirements for naval vessels

17.3.2 The reversing characteristics of the propulsion plant, including the blade pitch control system of controllable pitch propellers, are to be demonstrated and recorded during trials.

Existing paragraphs 17.3.2 and 17.3.4 have been renumbered 17.3.3 and 17.3.5.

~~17.3.5~~ 17.3.6 ~~Overloading of machinery is not to occur under continuous astern power.~~ For main propulsion systems with reversing gears, controllable pitch propellers or electric propeller drive, running astern is not to lead to the overload of any systems.

17.3.7 Steam turbine test requirements are to be agreed with LR, consideration is to be given to ventilation and intake arrangements in the astern direction. The duration of the astern trial is to be limited in accordance with manufacturer's recommendations to avoid overheating of the turbine due to the effects of 'windage' and friction.

Existing paragraphs 17.3.6 and 17.3.7 have been renumbered 17.3.8 and 17.3.9.

Volume 2, Part 2, Chapter 1
Reciprocating Internal Combustion Engines

■ *Section 1*
General requirements

1.1 Application

1.1.1 Engines providing power for Mobility or Ship Type systems are to be constructed under survey and in accordance with the requirements of this Chapter (*see also Vol 1, Pt 1, Ch 2, 3.9 Machinery and Engineering Systems notations*).

~~1.1.1~~ 1.1.2 This Chapter is to be read in conjunction with the requirements for Machinery and Engineering Systems in *Vol 2, Pt 1, Ch 1 General Requirements for Classification of Engineering Systems* and *Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems.* Specific attention is drawn to the transverse requirements in *Vol 2, Pt 1, Ch 3, 4 Operating conditions*.

1.2 Scope

~~1.1.4~~ 1.2.1 For the purposes of this Chapter engine type, expressed by the manufacturer/licensor’s designation, is defined by:
the bore and stroke;
the method of injection (i.e. direct injection, indirect injection, pilot injection);
the fuel pump and injection system (independent line to fuel oil valve, common rail);
the valve and injection operation (by cams or electronically controlled);
the fuel(s) used (liquid, dual-fuel, gaseous, etc.);
the working cycle (4-stroke, 2-stroke);
the gas exchange (naturally aspirated, turbocharged, etc.);
the method of turbocharging (pulsating system, constant pressure system);
the charging air cooling system (with or without intercooler, number of stages);
cylinder arrangement (in-line, vee, etc.);
the maximum continuous power per cylinder (or maximum continuous brake mean effective pressure) at maximum continuous speed;
the manufacturer and type of governor (and control system if applicable) fitted.

~~1.1.5~~ 1.2.2 A complete engine includes the control system, turbocharger(s) and all ancillary systems and equipment referred to in this Chapter that are used for operation of the engine for which there are rule requirements; this includes systems allowing the use of different fuel types.

1.2.3 Arrangements for dual fuel engines will be specially considered.

~~1.1.3~~ 1.2.4 Primary exhaust gas emissions abatement plant (where fitted) is to meet the requirements of this Chapter; additionally, it is to meet the requirements of *Vol 2, Pt 12 Emissions Abatement Plant*. Where secondary exhaust gas emissions abatement systems are fitted to engines, they are to meet the requirements of *Vol 2, Pt 12 Emissions Abatement Plant*.

~~1.2 Power ratings~~

~~1.2.1 In this Chapter where the dimensions of any particular component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in *Vol 2, Pt 1, Ch 3, 4.3 Power ratings*.~~

~~1.3 Power conditions for generator sets~~

~~1.3.1 Auxiliary engines coupled to electrical generators are to be capable under service conditions of developing continuously the power to drive the generators at full rated output (kW) and of developing for a short period (15 minutes) an overload power of not less than 10 per cent (*see Vol 2, Pt 9 Electrotechnical Systems*).~~

~~1.4 Inclination of ship~~

~~1.4.1 Main and auxiliary engines for Mobility systems or Ship Type systems are to operate satisfactorily under the conditions as shown in *Table 3.4.2 Inclinations*.~~

Existing sub-Section 1.5 has been moved to new Section 6.

■ ~~*Section 2*~~

~~Documents required for design review~~

~~2.1~~ 1.3 Approval process

~~2.1.1 Approval of an engine type will be granted following:~~

~~(a) satisfactory design appraisal. Plans are to be submitted as required in *Table 1.2.1 Plans and particulars to be submitted*.~~

~~(b) satisfactory type testing (*see Vol 2, Pt 2, Ch 1, 12.1 Engines*).~~

~~**Note** Approval of the engine type is not to be confused with LR Type Approval; LR Type Approval is explained in *Vol 1, Pt 1, Ch 2, 5.1 LR Type Approval* and *Vol 2, Pt 1, Ch 1, 9 Type approval system (for information).*~~

1.3.1 All engines intended for installation on an LR Class ship are to be type approved by LR (*see* LR Type Approval System Procedure TA14 for details of the LR Type Approval process).

~~2.1.2~~ 1.3.2 Each complete engine, as defined in *Vol 2, Pt 2, Ch 1, ~~1.1 Application 1.1.5~~ 1.2 Scope,* intended for installation on an LR Classed vessel, is to have an LR Engine Certificate.

~~2.1.3~~ 1.3.3 For the first engine of a type the approval process and the engine certification process may be performed simultaneously.

~~2.1.4~~ 1.3.4 To apply for an LR Engine Certificate, the following are to be submitted:

(a) a list of all documents identified in the ‘for information’ and ‘for appraisal’ columns of *Table ~~1.2.1~~ 1.1.1 Plans and particulars to be submitted* ~~Plans and particulars to be submitted~~ with the relevant drawing numbers and revision status. This list is to cross-reference the approved plans previously submitted ~~in accordance with *Vol 2, Pt 2, Ch 1, 2.1 Approval process 2.1.1*~~ as part of the engine Type Approval and identify any plans that have been modified.

where there is a licensor/licensee arrangement the list required by *Vol 2, Pt 2, Ch 1, ~~2.1~~ 1.3 Approval process ~~2.1.4~~ 1.3.4 (a)* is to cross-reference the drawings submitted by the designer ~~in accordance with *Vol 2, Pt 2, Ch 1, 1.1 Application 1.1.5*~~ as part of the engine Type Approval. This list is to identify all changes where the approved design has been modified by the licensee. Where the licensee proposes design modifications to components, a statement is to be made confirming the licensor’s acceptance of the proposed changes. If designer/licensor’s acceptance is not confirmed, the engine is to be regarded as a different type and is subject to the complete appraisal and type testing process.

all documents with changes from the approved design are to be submitted for review/appraisal. ~~In all cases the complete set of endorsed documents and the list referenced in *Vol 2, Pt 2, Ch 1, 2.1 Approval process 2.1.4*, which are to be provided by the manufacturer, will be required by the Surveyor(s) attending the manufacturer’s works. Where a licensee/licensor arrangement is in place, this set of documents may be a combination of licensor and licensee documents.~~

In all cases the complete set of endorsed documents and the list referenced in *Vol 2, Pt 2, Ch 1, 1.3 Approval process 1.3.4 (a)*, which are to be provided by the manufacturer, will be required by the Surveyor(s) attending the manufacturer’s works. Where a licensee/licensor arrangement is in place, this set of documents may be a combination of licensor and licensee documents.

~~2.1.5~~ 1.3.5 An LR Engine Certificate is issued upon satisfactory completion of engine assembly, with associated component testing (*see Vol 2, Pt 2, Ch 1, ~~3~~ 2 Materials and components*) and factory acceptance testing (*see Vol 2, Pt 2, Ch 1, ~~10~~ 11 Factory Acceptance Test and Shipboard Trials of Internal Combustion Engines)*~~. An alternative method of engine certification is available to manufacturers approved under the Quality Assurance Scheme for Machinery (QAM). *See Vol 2, Pt 1, Ch 1, 8 Quality assurance scheme for machinery.*~~ or issued in accordance with the alternative approach for product assurance approved by LR, *see Vol 2, Pt 1, Ch 1, 6.4 Alternative system of inspection*.

~~2.1.6~~ 1.3.6 For appraisal of emergency generator engines ~~sets~~ and turbochargers additional submissions are required. *See Vol 2, Pt 2, Ch 1, ~~2.2~~ 1.4 Submission requirements ~~2.2.4~~ 1.4.4* and *Vol 2, Pt 2, Ch 1, ~~2.2~~ 1.4 Submission requirements ~~2.2.5~~ 1.4.5*, as applicable.

~~2.1.7 Where required materials and components are to be manufactured, tested and certified at a manufacturer approved by LR in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as Rules for Materials), *see Vol 2, Pt 2, Ch 1, 3 Materials and components*.~~

~~2.2~~ 1.4 Submission requirements

1.4.1 The plans and information are to be submitted as required in *Table 1.1.1 Plans and particulars to be submitted* and *Vol 2, Pt 2, Ch 1, 1.4 Submission requirements 1.4.2* to *Vol 2, Pt 2, Ch 1, 1.4 Submission requirements 1.4.8* as applicable.

Table ~~1.2.1~~ 1.1.1 Plans and particulars to be submitted

Document	For information	For appraisal
	(X *indicates reason for submission)*	
Engine particulars (LR Form 2073 with general engine and ancillaries information, Project Guide, Marine Installation Manual), ~~(S~~*see* Note 1~~)~~	X	
Material specifications of principal components with information on non-destructive material tests and pressure tests		X
Engine cross-section	X	
Engine longitudinal section	X	
Engine frames, welding drawings, ~~(S~~*see* Notes 2 and 3~~)~~		X
Main engine foundation and holding down and securing arrangements	X (metal chocks)	X (non-metallic chocks)
Bedplate and crankcase of cast design	X	
Bedplate and crankcase of welded design, with welding details and welding instructions, ~~(S~~*see* Notes 2 and 3~~)~~		X
Bedplate/oil sump welding drawings, ~~(S~~*see Note* 2~~)~~		X
Thrust bearing assembly, ~~(S~~*see* Note 4~~)~~	X	
Thrust shaft or intermediate shaft (if integral with engine)		X
Thrust bearing bedplate of welded design, with welding details and welding instructions, ~~(S~~*see* Note 2~~)~~		X
Frame, ~~(S~~*see* Note 3~~)~~, framebox, ~~(S~~*see* Note 3~~)~~, and gearcase of cast construction	X	
Tie rod	X	
Connecting rod, assembly, ~~(S~~*see* Note 5~~)~~	X	
Crosshead, assembly, ~~(S~~*see* Note 5~~)~~	X	
Piston rod, assembly, ~~(S~~*see* Note 5~~)~~	X	
Piston, assembly, ~~(S~~*see* Note 5~~)~~	X	
Piston head	X	
Cylinder jacket/ block of cast construction, ~~(S~~*see* Note 3~~)~~	X	
Cylinder cover, assembly, ~~(S~~*see* Note 5~~)~~	X	
Cylinder liner	X	
Counterweights (if not integral with crankshaft), including fastening	X	
Crankshaft, details (for each crankthrow)		X
Crankshaft, assembly (for each crankthrow)		X
Crankshaft calculations (~~S~~*see Vol 2, Pt 2, Ch 1,* ~~*4*~~ *3 Crankshaft design*)	X	
Camshaft drive, assembly, ~~(S~~*see* Note 5~~)~~	X	
Flywheel or turning-wheel	X	
Shaft coupling interface arrangement including dimensions and material details		X
Details of shielding and insulation of exhaust pipes and other parts operating at an elevated temperature, which might be impinged by flammable fluid(s) as a result of a system failure	X	
Schematic layout or other equivalent documents for the engine, ~~(S~~*see* Note 6~~)~~:		
• Starting and control air systems		X
• Fuel system		X
• Lubricating oil system		X
• Cooling water system		X
• Hydraulic systems		X
• Engine control and safety system		X
High pressure fuel injection pump assembly	X	
High pressure parts for fuel oil injection system, ~~(S~~*see* Note 7~~)~~		X
Shielding arrangements for high pressure piping - fuel, hydraulic and flammable oils (~~S~~*see Vol 2, Pt 2, Ch 1, 8.1* ~~*Oil fuel*~~ *Fuel Oil, hydraulic and high-pressure oil systems 8.1.1*)		X

Fastening arrangements for main bearings	X	
Fastening arrangements for cylinder heads and exhaust valve (two stroke design)	X	
Fastening arrangements for connecting rods	X	
Vibration dampers/detuners and moment compensators	X	
Construction and arrangement of vibration dampers	X	
Details of mechanical joints of piping systems		X
Oil mist detection and/or alternative arrangements		X
Construction of accumulators for electronically controlled engine		X
Construction of common accumulators for electronically controlled engine		X
Construction of accumulators for hydraulic oil and fuel oil		X
Arrangement and details of the crankcase explosion relief valve where applicable (~~*S*~~*see* ~~*Vol 2, Pt 2, Ch 1, 10 Factory Acceptance Test and Shipboard Trials of Internal Combustion Engines*~~ *Vol 2, Pt 2, Ch 1, 10 Safety arrangements*)		X
Calculation results for crankcase explosion relief valves (~~*S*~~*see* ~~*Vol 2, Pt 2, Ch 1, 10 Factory Acceptance Test and Shipboard Trials of Internal Combustion Engines*~~ *Vol 2, Pt 2, Ch 1, 10 Safety arrangements*)		X
Construction and arrangements of hydraulic systems for actuation of sub-systems:		
• Control valves, high-pressure pumps, pipes and accumulators	X	
• Drive for high pressure pumps	X	
• Valve bodies, if applicable	X	
For engine control, alarm monitoring and safety systems, the plans and information *Vol 2, Pt 2, Ch 1, ~~2.2~~ 1.4 Submission requirements ~~2.2.2~~ 1.4.3*, ~~(*S*~~*see* Note 8~~)~~		X
Generator set test results that state the engine maximum load steps which satisfy the quality of power supply requirements specified in *Vol 2, Pt 9, Ch 1, 2.1 Quality of power supplies (QPS)*)		X
Planned operating profiles for the vessel at sea and during manoeuvring as agreed with the Operators		X
List of sub-contractors for main parts	X	
Operation and service manuals, ~~(*S*~~*see* Note 9~~)~~	X	
Risk-based analysis (for engine control system) , ~~(*S*~~*see* Note 10~~)~~	X	
Test program resulting from risk-based analysis (for engine control system) , ~~(*S*~~*see* Note 10~~)~~	X	
Production specifications for castings and welding procedures	X	
Evidence of quality control system for engine design, production and in-service maintenance, ~~(*S*~~*see* Notes 5 and 11~~)~~	X	
Type approval certification for environmental tests of control components, ~~(*S*~~*see* Note 12~~)~~	X	
Details of the engine type test program and the type test report, ~~(*S*~~*see* Note 13~~)~~		X
~~Fatigue analysis for all high pressure oil fuel and hydraulic oil piping arrangements (*See* Note 14)~~		~~X~~
Engine test schedule (FAT and shipboard trials, *see Vol 2, Pt 2, Ch 1, ~~2.2~~ 1.4 Submission requirements ~~2.2.1~~ 1.4.2*)		X
Documentation verifying compliance with inclination limits (~~*S*~~*see Vol 2, Pt 1, Ch 3, 4.6 Inclination of ship*)		X
Combustion pressure~~-~~–displacement relationship		X
Plans and details for dead ship condition starting arrangements, *see Vol 2, Pt 7, Ch 3, 12.11 Dead ship condition starting arrangements*.		X

Note 1. LR Form 2073 will be supplied on application. Note that the turbochargers, if required to be ~~type approved~~ Type Approved, are to have plans and particulars submitted as detailed in *Vol 2, Pt 2, Ch 1,~~ 2.2~~ 1.4 Submission requirements ~~2.2.4~~ 1.4.5*.

Note 2. For approval of materials and weld procedure specifications. The weld procedure specification is to include details of pre- and post-weld heat treatment, weld consumables and fit-up conditions.

Note 3. For each cylinder for which dimensions and details differ.

Note 4. If integral with engine and not integrated in the bedplate.

Note 5. Including identification of components to ensure traceability in accordance with the Rules for Materials.

Note 6. Details of the system so far as supplied by the engine manufacturer such as: main dimensions, operating media and maximum working pressures.

Note 7. The documentation to contain specifications for pressures, pipe dimensions and materials.

Note 8. The ~~System Design Description required by *Table 1.2.2 Additional Plans and particulars to be submitted*~~ submission is to include a general overview of the operating principles, supported by schematics explaining the functionality of individual systems and sub-systems. The information is to relate to the engine capability and functionality under defined operating and emergency conditions such as recovery from a failure or malfunction, with particular reference to the functioning of programmable electronic systems and any sub-systems. The information is also to indicate if the engine has different modes of operation, such as to limit exhaust gas emissions and/or to run under an economic fuel consumption mode or any other mode that is electronically controlled.

Note 9. Operational manuals are to contain maintenance requirements (servicing and repair) including details of any special tools and gauges that are to be used with their fitting/settings together with any test requirements on completion of maintenance. They are to include a description of each system's particulars and include reference to the functioning of sub-systems.

Note 10. Where engines rely on hydraulic, pneumatic or electronic control of fuel injection and/or valves, the risk-based analysis is to address the mechanical, pressure containing, electrical, electronic and programmable electronic systems and arrangements that support the operation of the engine. It is to demonstrate that failure of the control system will not result in the operation of the engine being degraded beyond acceptable performance criteria for the engine and that suitable risk mitigation has been achieved in accordance with *Vol 2, Pt 2, Ch 1, ~~4.2~~ 3.3 Information to be submitted*. The risk-based analysis will not be explicitly approved by LR.

Note 11. Including quality plan for sourcing, traceability, design, installation and testing of all components used in the fuel and hydraulic oil systems installed with the engine. *See Vol 2, Pt 2, Ch 1, 8.1 ~~Oil fuel~~ Fuel Oil, hydraulic and high-pressure oil systems ~~8.1.11~~ 8.1.10*.

Note 12. Tests are to demonstrate the ability of the control, protection and safety equipment to function as intended under the specified testing conditions as per Lloyd's Register Type Approval Test Specification Number 1.

Note 13. The type test report may be submitted shortly after the conclusion of the type test. For electronically controlled engines evidence of type testing of the engine with the programmable electronic system, or a proposed factory acceptance test plan at the engine builders with the programmable electronic system functioning, is to be submitted to verify the functionality and behaviour under normal operating and fault conditions of the programmable electronic control system. Where required this is to include proposals for short-term, high power operation.

~~Note 14. Required for engine operation where failure of the pipe or its connection or a component would be the cause of engine unavailability. The analysis is to concentrate on high pressure components and sub-systems and recognise the pressures and fluctuating stresses that the pipe system may be subject to in normal service.~~

~~2.2.1~~ 1.4.2 A ~~S~~schedule of testing at the engine packager's or system integrator's facility, pre-sea trial commissioning and sea trials is to be submitted. The test schedules are to identify all modes of engine operation and the sea trials are to include typical port manoeuvres under all intended engine operating modes. The schedule is to include:

(a) testing and trials to demonstrate that the engine is capable of operating as described in *Table ~~1.2.1~~ 1.1.1 Plans and particulars to be submitted*, Note ~~8~~ 10;

tests to verify that the response of the complete mechanical, hydraulic, electrical and electronic system is as predicted for the intended operational modes; and

testing required to verify the conclusions of the risk-based analysis.

The scope of these tests is to be agreed with LR based on the risk-based analysis.

~~2.2.2~~ 1.4.3 In addition to the applicable plans and particulars required by *Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review ~~1.4.5~~* ~~to~~ ~~*Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.8*~~, the following information for control, alarm, monitoring and safety systems relating to the operation of an electronically controlled engine is to be submitted:

(a) Engine configuration details, *see Vol 2, Pt 2, Ch 1, ~~13.3~~ 4.3 Control engineering systems ~~13.3.2~~ 4.3.2.*

   (i) Local and remote means to carry out system configuration.

   (ii) Engine builder procedures for undertaking configuring.

   (iii) Roles and responsibilities for configuration (e.g. Engine builder, engine packager, system integrator or other nominated party) with accompanying schedule.

   (iv) Configurable settings and parameters (including those not to be modified from a default value).

   (v) Configuration for propulsion, auxiliary or emergency engine application.

   ~~Configuration records are to be maintained and are to be made available to the Surveyor at testing and trials and on request in accordance with *Vol 2, Pt 9, Ch 1, 1.7 Alterations and additions* and *Vol 2, Pt 9, Ch 11, 1.2 Trials 1.2.3*.~~

Software quality plans, including configuration management documents.

Software safety evidence.

Software assessment inspection report such as SCA or IEC 61508, as applicable.

Configuration records are to be maintained and are to be made available to the Surveyor at testing and trials and on request in accordance with *Vol 2, Pt 9, Ch 1, 1.7 Alterations and additions* and *Vol 2, Pt 9, Ch 11, 1.2 Trials 1.2.3*.

~~2.2.3~~ 1.4.4 ~~For emergency engines, evidence and details showing compliance with~~ Emergency generator engine plans, information and test schedules, required for design appraisal, are to be in accordance with ~~*Vol 2, Pt 2, Ch 1, 13.5 Emergency engines*~~ *Vol 2, Pt 9, Ch 2 Electrical Power Generator and Energy Storage*.

~~2.2.4~~ 1.4.5 For turbochargers, the following plans and particulars are to be submitted. ~~for information:~~ The submission requirements vary depending on the category of the turbocharger; category A, B and C turbochargers are defined in *Vol 2, Pt 2, Ch 1, 12.1 General 12.1.2*:

~~(a) Cross-sectional drawing with principal dimensions and materials of housing components for containment evaluation.~~

~~Drawings of the housing and rotating parts including details of blade fixing.~~

~~Material specifications (chemical composition and mechanical properties) of all parts mentioned in (b) above including details of the material and quality control system to be used for these parts.~~

~~Welding details and welding procedure of above mentioned parts, if applicable.~~

~~Documentation of containment in the event of disc fracture, *see Vol 2, Pt 2, Ch 1, 11.5 Containment*.~~

~~Type test reports.~~

~~Operational data and limitations, i.e.:~~

- ~~Maximum permissible operating speed (rpm)~~
- ~~Alarm level for over-speed~~
- ~~Maximum permissible exhaust gas temperature before turbine~~
- ~~Alarm level for exhaust gas temperature before turbine~~

- ~~Minimum lubrication oil inlet pressure~~
- ~~Lubrication oil inlet pressure low alarm set point~~
- ~~Maximum lubrication oil outlet temperature~~
- ~~Lubrication oil outlet temperature high alarm set point~~
- ~~Maximum permissible vibration levels, i.e. self- and externally generated vibration (Alarm levels may be equal to permissible limits but are not to be reached when operating the engine at 110 per cent power or at any approved intermittent overload beyond 110 per cent.)~~

~~Arrangement of lubrication system, all variants within a range.~~
~~A list of main current suppliers and subcontractors for rotating parts and an operation and maintenance manual.~~
~~Documentation* of safe torque transmission when the disc is connected to the shaft by an interference fit, see Vol 2, Pt 2, Ch 1, 11.6 Disk-shaft shrinkage fit.~~
~~Information on expected lifespan, considering creep, low cycle fatigue and high cycle fatigue.~~
~~Operation and maintenance manuals*.~~
~~Note * Applicable to two sizes in a generic range of turbochargers.~~

Category A (on request):
- (i) Turbocharger specification including type, compression ratio and operating condition.
- (ii) Cross-sectional drawing with principal dimensions and names of components.
- (iii) Containment test report.
- (iv) Test program.

Category B:
- (i) Turbocharger specification including type of turbine and compressor, compression ratio, bearing and cooling method.
- (ii) Cross-sectional drawing with principal dimensions and materials of housing components for containment evaluation.
- (iii) Documentation of containment in the event of disc fracture.
- (iv) Operational data and limitations, i.e.:
  - Maximum permissible operating speed (rpm);
  - Alarm level for overspeed;
  - Maximum permissible exhaust gas temperature before turbine;
  - Alarm level for exhaust gas temperature before turbine;
  - Minimum lubrication oil inlet pressure;
  - Lubrication oil inlet pressure low alarm set point;
  - Maximum lubrication oil outlet temperature;
  - Lubrication oil outlet temperature high alarm set point;
  - Maximum permissible vibration levels, i.e. self- and externally generated vibration;

  (Alarm levels may be equal to permissible limits but are not to be reached when operating the engine at 110 per cent power or at any approved intermittent overload beyond 110 per cent.).
- (v) Arrangement of lubrication system, all variants within a range.
- (vi) A list of main current suppliers and subcontractors for rotating parts and an operation and maintenance manual.
- (vii) Type test reports.

Category C:
- (i) Plans and particulars as for Category B.
- (ii) Drawings of the housing and rotating parts (shaft, wheels, blades and nozzle) including details of blade fixing for turbine and compressor.
- (iii) Material specifications (including density, Poisson's ratio, range of chemical composition and mechanical properties (at room temperature), and high-temperature strength characteristics as well as creep rate and rupture strength for the design service life (parts subject to 450 degrees Celsius or more)) of all parts mentioned above including details of the material and quality control system to be used for these parts.
- (iv) Welding details and welding procedure of above-mentioned parts, if applicable.
- (v) Documentation* of safe torque transmission when the disc is connected to the shaft by an interference fit.
- (vi) Information on expected lifespan, considering creep, low cycle fatigue and high cycle fatigue.
- (vii) Operation and maintenance manuals*.
- (viii) Arrangements of cooling system.

  Note * Documentation is to be provided applicable to two representative sizes in a generic range of turbochargers.

~~2.2.6~~ 1.4.6 Where considered necessary ~~Lloyd's Register (hereinafter referred to as 'LR')~~ LR may require additional documentation to be submitted.

~~2.2.5~~ 1.4.7 The following information is to be submitted to LR for acceptance of oil mist detection equipment and alarm arrangements:

(a) Description of oil mist detection equipment and system including alarms.

Copy of the test house report in accordance with the requirements of Test Specification No. 4. *See also Vol 2, Pt 2, Ch 1, ~~12.4~~ 13.4 Crankcase oil mist detection system.*

Schematic layout of engine oil mist detection arrangements showing location of detectors/sensors and piping arrangements and dimensions.

Maintenance and test manual which is to include the following information:
- (i) Intended use of equipment and its operation;
- (ii) Functionality tests to demonstrate that the equipment is operational and that any faults can be identified and corrective actions notified;
- (iii) Maintenance routines and spare parts recommendations;
- (iv) Limit setting and instructions for safe limit levels; and
- (v) Where necessary, details of configurations in which the equipment is and is not to be used.

~~2.2.7~~ 1.4.8 Where engine components are subject to autofrettage, the following information is to be submitted (*see also Vol 2, Pt 2, Ch 1, ~~3.5~~ 2.4 Autofrettage*):

(a) Drawings and other related documents/information for products to be subjected to autofrettage, including material grade and dimensions.
(b) Details of product quality assurance processes.
(c) Place of manufacture and details of external providers of products subjected to autofrettage.
(d) A report detailing how repeatability and reliability of the autofrettage process is achieved. This is to include the following:
    (i) method of autofrettage;
    (ii) method to control extent of autofrettage;
    (iii) calibration of the autofrettage system; and
    (iv) details of how the critical parameters affecting product characteristics are controlled.
(e) Method for recording results and list of data that is recorded.
(f) Finished component and/or system testing.

~~2.3~~ 1.5 Additional submission requirements for naval vessels

~~2.3.1~~ 1.5.1 In addition to the requirements of *Vol 2, Pt 2, Ch 1, ~~2.2~~ 1.4 Submission requirements* and *Table ~~1.2.1~~ 1.1.1 Plans and particulars to be submitted*, the plans and information in *Vol 2, Pt 2, Ch 1, ~~2.3~~1.5 Additional submission requirements for naval vessels ~~2.3.2~~ 1.5.2 and Table ~~1.2.2~~ 1.1.2 ~~Additional~~ Plans and particulars to be submitted for naval vessels* are to be submitted.

~~2.3.2~~ 1.5.2 Risk Assessment (RA) as required by *Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems* is to be submitted. The RA is to be carried out in accordance with the requirements of *Vol 2, Pt 1, Ch 3, 18 Risk Assessment (RA)* and is to include the following associated sub-systems:

- Starting and stopping.
- Fuel oil.
- Lubricating oil.
- Cooling water (fresh and sea).
- Air induction.
- Exhaust.
- Engine mounting.
- Control and monitoring.
- Electrical power supplies.
- Hydraulic oil (for valve lift).

It is not necessary to consider failure modes relating to the engine components.

Table ~~1.2.2~~ 1.1.2 ~~Additional~~ Plans and particulars to be submitted for naval vessels

Document	For information	For appraisal
	(X *indicates reason for submission)*	
Control engineering aspects in accordance with *Vol 2, Pt 9 Electrotechnical Systems*.		X
Details of the securing and collision arrangements (*see also Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.5* and *Vol 2, Pt 1, Ch 3, 5.3 Machinery fastenings* to *Vol 2, Pt 1, Ch 3, 5.7 Resin chocks*).		X
Arrangement of interior lighting, where provided.		X
Calculations and information for short-term high power operation where applicable.	X	
Power/speed operational envelope.	X	
Where it is proposed to use alloy castings, micro alloyed or alloy steel forgings or iron castings: Details of the chemical composition, heat treatment and mechanical properties.		X
System Operational Concept covering the Propulsion system, *see Vol 2, Pt 1, Ch 3, 3.4 System operational concept*.		X
System Design Description for engine systems, *see Vol 2, Pt 1, Ch 3, 3 Documentation required for design review*.		X

■ *Section ~~3~~ 2*
Materials and components

~~3.1~~ 2.1 Crankshaft materials

~~3.1.1~~ 2.1.1 The specified minimum tensile strength of castings and forgings for crankshafts is to be selected within the following general limits:

(a) Carbon-manganese steel castings –
400 to 550 N/mm^2.
(b) Carbon-manganese steel forgings (normalised and tempered) –
400 to 600 N/mm^2.
(c) Carbon-manganese steel forgings (quenched and tempered) –
not exceeding 700 N/mm^2.
(d) Alloy steel castings –
not exceeding 700 N/mm^2.
(e) Alloy steel forgings –
not exceeding 1000 N/mm^2.
(f) Spheroidal or nodular graphite iron castings –
370 to 800 N/mm^2.

2.1.2 Where it is proposed to use alloy castings, micro alloyed or alloy steel forgings or iron castings, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

3.2 Materials test and inspections

Existing sub-Section 3.2 has been renumbered 2.2.

~~3.3 Hydraulic tests~~

~~3.3.1 In general, items are to be tested by hydraulic pressure as indicated in *Table 1.3.1 Test and certification requirements for engine components*. Where design features are such that modifications to the test requirements shown in *Table 1.3.1 Test and certification requirements for engine components* are necessary, alternative proposals for hydraulic tests are to be submitted for special consideration.~~

~~3.3.2 Where a manufacturer has demonstrated to LR that they have an acceptable quality management system, a manufacturer's hydraulic test certificate may be accepted for engine driven pumps as detailed in *Table 1.3.1 Test and certification requirements for engine components*. Recognition and acceptance of the works quality control processes can be by one of the following routes:~~
~~(a) Approval under the LR Quality Assurance Scheme for Machinery (QAM).~~
~~(b) Approval of an alternative quality scheme recognized by LR.~~
~~(c) Approval by LR through auditing of the manufacturer's quality system.~~

Existing sub-Sections 3.4 and 3.5 have been renumbered 2.3 and 2.4.

■ *Section 4 3*
Crankshaft design

Existing Section 4 has been deleted in its entirety and replaced with below.

3.1 Application

3.1.1 The requirements of *Vol 2, Pt 2, Ch 1, 3 Crankshaft design* apply to engines of powers greater that 110 kW intended for mobility or ship type systems.

3.2 Scope

3.2.1 The formulae given in this Section are applicable to solid or semi-built crankshafts of forged or cast steel, having a main support bearing adjacent to each crankpin.

3.2.2 This section uses the static determinate method; alternative methods, including a fully documented stress analysis, will be considered.

3.2.3 Calculations are to be carried out for the maximum continuous power rating for all designed operating conditions. Calculations are to include short-term high power operation where applicable.

3.2.4 Designs of crankshafts not included in this scope will be subject to special consideration.

3.2.5 Where a crankshaft design involves the use of surface treated fillets, or when fatigue parameter influences are tested, or when working stresses are measured, the relevant documents with calculations/analysis are to be submitted to LR.

3.2.6 The design of crankshafts is based on an evaluation of safety against fatigue in the highly stressed areas. The calculation is also based on the assumption that the areas exposed to highest stresses are :

(a) fillet transitions between the crankpin and web as well as between the journal and web,
(b) outlets of crankpin oil bores.

3.2.7 When the journal diameter is equal to or larger than the crankpin one, the outlets of main journal oil bores are to be formed in a similar way to the crankpin oil bores, otherwise separate documentation of fatigue safety will be specially considered.

3.2.8 Calculation of crankshaft strength consists initially in determining the nominal alternating bending (*see Vol 2, Pt 2, Ch 1, 3.6 Calculation of bending stresses*) and nominal alternating torsional stresses (*see Vol 2, Pt 2, Ch 1, 3.7 Calculation of torsional stresses*) which, multiplied by the appropriate stress concentration factors (SCF) (*see Vol 2, Pt 2, Ch 1, 3.8 Stress concentration factors*), result in an equivalent alternating stress (uniaxial stress) (*see Vol 2, Pt 2, Ch 1, 3.10 Equivalent alternating stress*). This equivalent alternating stress is then compared with the fatigue strength of the selected crankshaft material (*see Vol 2, Pt 2, Ch 1, 3.11 Fatigue strength*). This comparison will show whether or not the crankshaft concerned is dimensioned adequately (*see Vol 2, Pt 2, Ch 1, 3.12 Acceptability criteria*).

3.2.9 Further information and guidance for crankshaft design is provided in the LR *Guidance Notes for Crankshaft SCF Calculation using Finite Element Method* and *Guidance for the Evaluation of Crankshaft Fatigue Tests.*

3.3 Information to be submitted

3.3.1 For the calculation of crankshafts, the documents and particulars listed below are required, this information is provided by completing LR Form 2073 and submitting the applicable plans required in *Table 1.1.1 Plans and particulars to be submitted*:

- Crankshaft drawing (which must contain all data in respect of the geometrical configurations of the crankshaft);
- Type designation and kind of engine (in-line engine or V-type engine with adjacent connecting rods, forked connecting rod or articulated-type connecting rod);
- Operating and combustion method (2-stroke or 4-stroke cycle/direct injection, precombustion chamber, etc.);
- Number of cylinders;
- Output power at maximum continuous rating (MCR), in kW;
- Output speed at maximum continuous power, in rpm;
- Maximum firing pressure, P_{max}, in MPa;
- Mean indicated pressure, in MPa;
- Charge air pressure (before inlet valves or scavenge ports, whichever applies), in MPa;
- Digitised gas pressure/crank angle cycle for MCR (presented at equidistant intervals at least every 5° CA);
- Mean piston speed;
- Compression ratio;
- Vee angle α_v, in degrees;
- Firing order numbered from driving end, *see Figure 1.3.1 Designation of cylinders;*
- Direction of rotation;
- Cylinder diameter, in mm;
- Piston stroke, in mm;
- Centre of gravity of connecting rod from large end centre, in mm;
- Radius of gyration of connecting rod, in mm;
- Length of connecting rod between bearing centres, L_H, in mm;
- Mass of single crankweb (indicate if webs either side of pin are of different mass values), in kg;
- Centre of gravity of crankweb mass from shaft axis, in mm;
- Mass of counterweights fitted (for complete crankshaft) indicate positions fitted, in kg;
- Centre of gravity of counterweights (for complete crankshaft) measured from shaft axis, in mm;
- All individual reciprocating masses acting on one crank, in kg;
- Crankshaft material specification(s) (according to ISO, EN, DIN, AISI, etc.);
- Mechanical properties of material (minimum values obtained from longitudinal test specimens):
    - tensile strength, in N/mm²
    - yield strength, in N/mm²
    - reduction in area at break, percentage
    - elongation, percentage
- Method of manufacture (free form forged, continuous grain flow forged, drop-forged, etc.; with description of the forging process);
- For semi-built crankshafts – minimum and maximum diametral interference, in mm;
- Particulars of alternating torsional stress calculations, *see Vol 2, Pt 2, Ch 1, 3.7 Calculation of torsional stresses*.

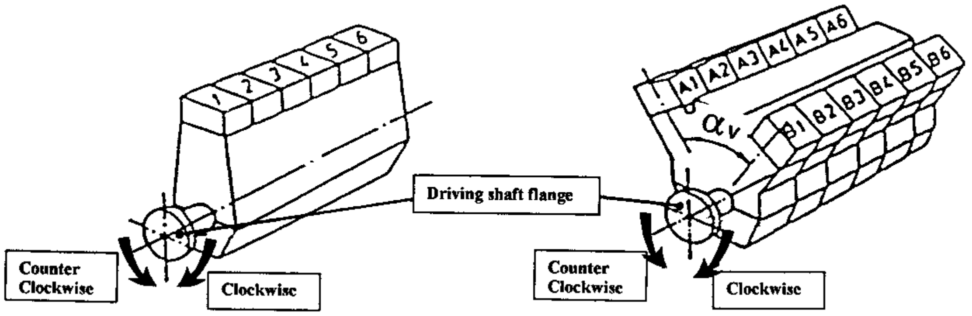


Figure 1.3.1 Designation of cylinders

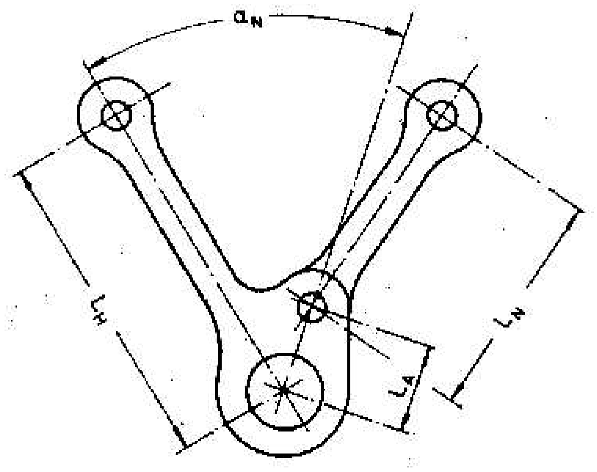


Figure 1.3.2 Articulated-type connecting rod

3.3.2 The following information is also required for appraisal of the crankshaft (not contained in Form 2073):

- For engines with articulated-type connecting rod (*see Figure 1.3.2 Articulated-type connecting rod*):
  - Distance to link point L_A, in mm
  - Link angle α_N, in degrees
  - Connecting rod length L_N, in mm
- firing interval (if applicable) i.e. if not evenly distributed
- Mass of connecting rod (including bearings), in kg;
- Mass of piston (including piston rod and crosshead where applicable), in kg;
- Every surface treatment affecting fillets or oil holes shall be specified so as to enable calculation according to Chapter 2 of the LR *Guidance Notes for Crankshaft SCF Calculation using Finite Element Method;*
  - This is to include Crankshaft fatigue enhancement factors K_1 and K_2 where applicable.
- Maximum alternating torsional stress τa (N/mm^2)
- Mechanical properties of material (minimum values obtained from longitudinal test specimens), in addition to the information listed above:

Impact energy K_V, in Joules

3.4 Symbols

3.4.1 For the purposes of this Chapter the following symbols apply, *see also*;

- *Figure 1.3.3 Crank dimensions for overlapped crankshaft*,
- *Figure 1.3.4 Crank dimensions for crankshaft without overlap*,
- *Figure 1.3.5 Crankpin section through the oil bore* and
- *Figure 1.3.6 Crankthrow of semi-built crankshaft*:

B = transverse breadth of web, in mm

D = crankpin diameter, in mm

D_A = the outside diameter of web or twice the minimum distance between centre-line of journals and outer contour of web, whichever is less, in mm

D_{BH} = diameter of axial bore in crankpin

D_{BG} = diameter of axial bore in journal
D_G = journal diameter

D_o = diameter of radial oil bore in crankpin, in mm

D_s = shrink diameter of main journal in web, in mm

E = pin eccentricity

E_m = Young’s modulus of crankshaft material, in N/mm^2

F = area related to cross-section of web, in mm^2

K_e = bending stress factor (considers the influence of adjacent crank and bearing restraint)

K = fatigue enhancement factor ($K = K_1 . K_2$)

K_1 = fatigue enhancement factor due to manufacturing process

K_2 = fatigue enhancement factor due to surface treatment

L_s = length of shrink fit, in mm

M_{BON} = alternating bending moment calculated at the outlet of crankpin oil bore

M_{BRFN} = alternating bending moment related to the centre of the web, in Nm

M_{TN} = maximum alternating torque, in Nm

M_{Tmax} = maximum value of the torque, in Nm

M_{Tmin} = minimum value of the torque, in Nm

Q_{RFN} = alternating radial force related to the web, in N

R_H, R_G = fillet radius at junction of web and pin or journal, in mm

S = pin overlap, in mm $S = \frac{D + D_G}{2} - E$

T_H, T_G = recess of pin or journal fillet radius into web measured from web face, in mm

W = axial thickness of web, in mm

W_{eqw} = section modulus related to cross-section of web, in mm^3

W_e = section modulus related to cross-section of axially bored crankpin, in mm^3

W_p = polar section modulus related to cross-section of axially bored crankpin or bored journal, in mm^3

y = distance between the adjacent generating lines of journal and pin, in mm

Note: $y \geq 0{,}05 D_S$, where y is less than $0{,}1 D_S$ special consideration is to be given to the effect of the stress due to the shrink fit on the fatigue strength at the crankpin fillet.

α_B = bending stress concentration factor for crankpin fillet

α_T = torsional stress concentration factor for crankpin fillet

β_B = bending stress concentration factor for main journal fillet
Note. α_B and β_B are defined as the ratio of the maximum equivalent stress (von Mises) occurring in the fillets under bending load, to the nominal bending stress related to the web cross-section. *See Figure 1.3.7 Stress concentration factors in crankshaft fillets*.

β_Q = compression stress concentration factor for main journal fillet

Note. β_Q is defined as the ratio of the maximum equivalent stress (von Mises) occurring in the fillet due to the radial force, to the nominal compressive stress related to the web cross-section.

β_T = torsional stress concentration factor for main journal fillet

Note. α_T and β_T are defined as the ratio of the maximum equivalent shear stress occurring in the fillets under torsional load, to the nominal torsional stress related to the axially bored crankpin or journal cross-section. *See Figure 1.3.7 Stress concentration factors in crankshaft fillets*.

γ_B = bending stress concentration factor for outlet of crankpin oil bore

γ_T = torsional stress concentration factor for outlet of crankpin oil bore

Note: γ_B and γ_T are defined as the ratio of the maximum principal stress occurring at the outlet of the crankpin oil-hole under bending and torsional loads respectively, to the corresponding nominal stress related to the axially bored crankpin cross section. *See Figure 1.3.8 Stress concentration factors and stress distribution at the edges of oil drillings.*

σ_{add} = additional bending stress due to misalignment and bedplate deformation as well as due to axial and bending vibrations

σ_B = specified minimum UTS of crankshaft material, in N/mm^2

σ_{BFN} = nominal alternating bending stress related to the web, in N/mm^2

σ_{BG} = alternating bending stress in journal fillet, in N/mm^2

σ_{BH} = alternating bending stress in crankpin fillet, in N/mm^2

σ_{BO} = alternating bending stress in the outlet of the oil bore, in N/mm^2

σ_{BON} = nominal alternating bending stress in the outlet of the oil bore related to the crankpin diameter, in N/mm^2

σ_{QFN} = nominal alternating compressive stress due to radial force related to the web, in N/mm^2

σ_{DW} = allowable fatigue strength of crankshaft, in N/mm^2

σ_{SP} = minimum yield strength of material for journal pin, in N/mm^2

σ_{SW} = minimum yield strength of material for crankweb, in N/mm^2

σ_{TO} = alternating torsional stress in the outlet of the crankpin oil bore, in N/mm^2

σ_y = equivalent alternating stress for crankpin fillet, journal fillet or outlet of crankpin oil bore as applicable, in N/mm^3

τ_H = alternating torsional stress in crankpin fillet, in N/mm^2

τ_G = alternating torsional stress in journal fillet, in N/mm^2

τ_N = calculated nominal alternating torsional stress referred to crankpin or journal (as applicable), in N/mm^2

τ_a = manufacturer stated crankshaft half range torsional stress limit, in N/mm^2

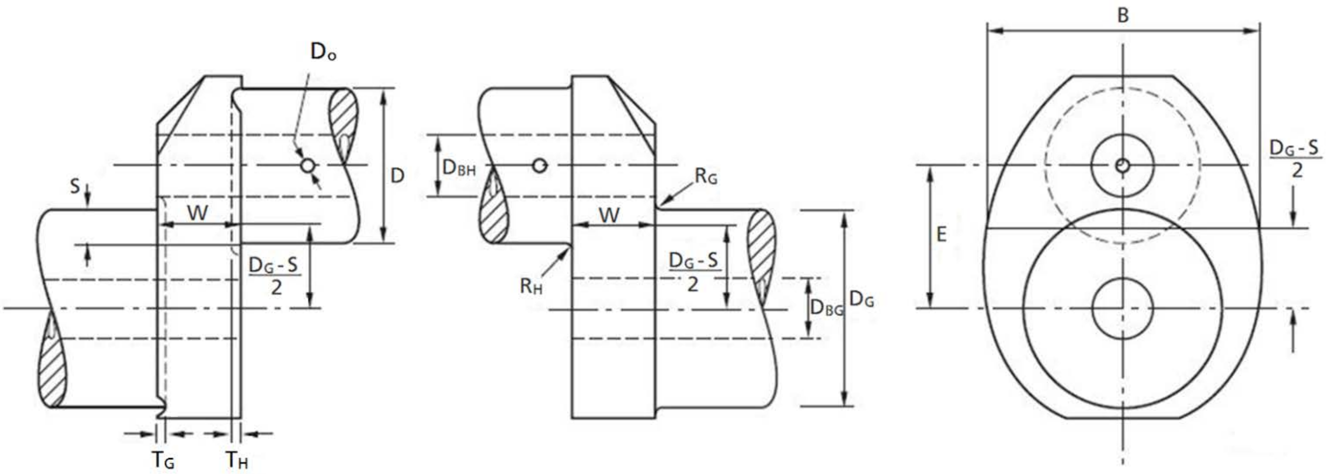


Figure 1.3.3 Crank dimensions for overlapped crankshaft

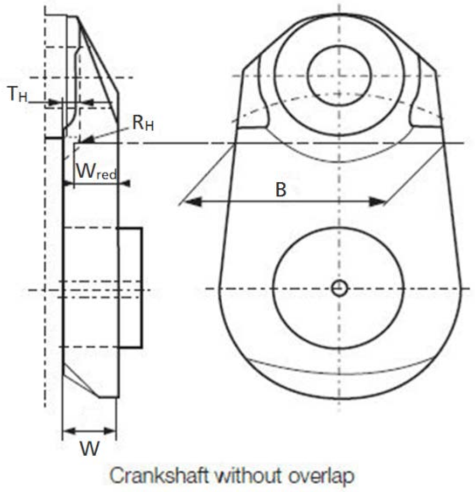


Figure 1.3.4 Crank dimensions for crankshaft without overlap

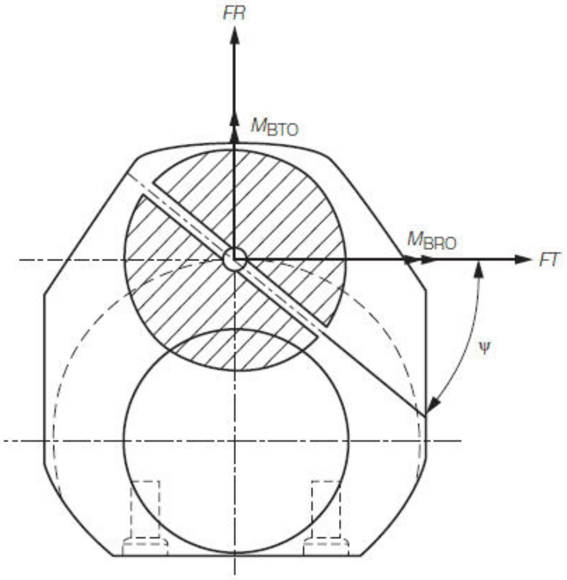


Figure 1.3.5 Crankpin section through the oil bore

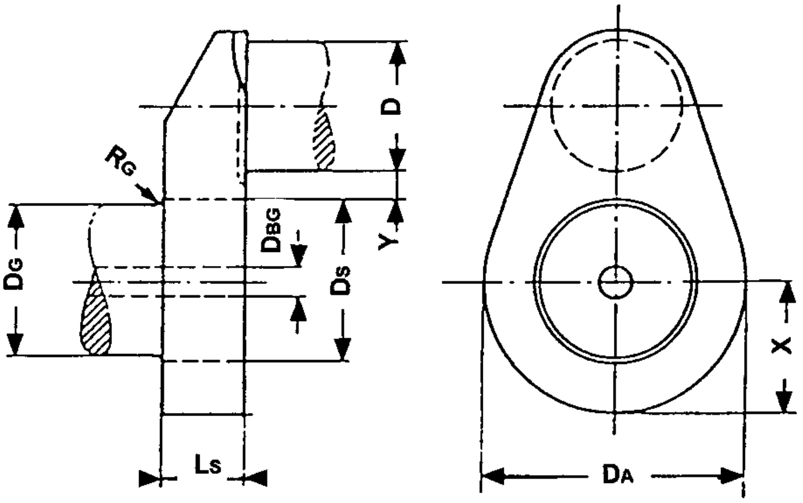
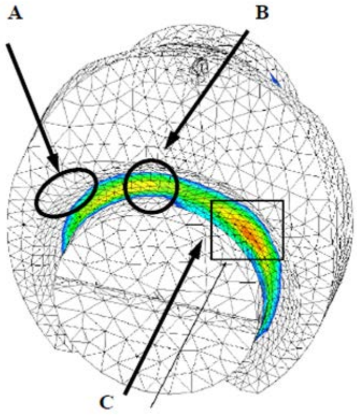


Figure 1.3.6 Crankthrow of semi-built crankshaft



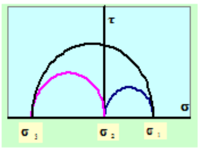
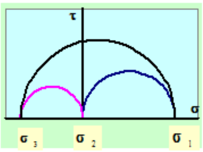
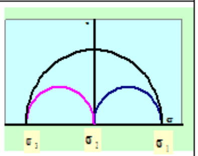
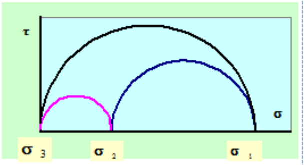
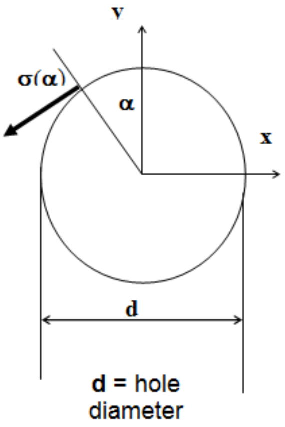
Stress Type	Stress	Max $\|\|\sigma_3\|\|$	Max σ_1	
Torsional loading	Location of maximal stresses	*A*	*C*	*B*
	Typical principal stress system Mohr's circle diagram with $\sigma_2 = 0$	 $\|\|\sigma_3\|\| > \sigma_1$	 $\sigma_1 > \|\|\sigma_3\|\|$	 $\sigma_1 \approx \|\|\sigma_3\|\|$
	Equivalent stress and **S.C.F**.	$\tau_{equiv} = \frac{\sigma_1 - \sigma_3}{2}$ $S.C.F. = \frac{\tau_{equiv}}{\tau_n}$ for α_T, β_T		
Bending loading	Location of maximal stresses	*B*	*B*	*B*
	Typical principal stress system Mohr's circle diagram with $\sigma_3 = 0$			$\sigma_2 \neq 0$
	Equivalent stress and **S.C.F**.	$\sigma equiv = \sqrt{\sigma_1{}^2 + \sigma_2{}^2 - \sigma_1 . \sigma_2}$ $S.C.F. = \frac{\sigma equiv}{\sigma_n}$ for $\alpha_B, \beta_B, \beta_Q$		

Figure 1.3.7 Stress concentration factors in crankshaft fillets



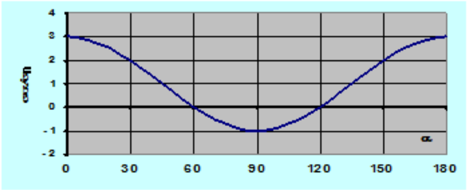
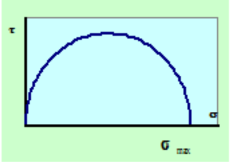
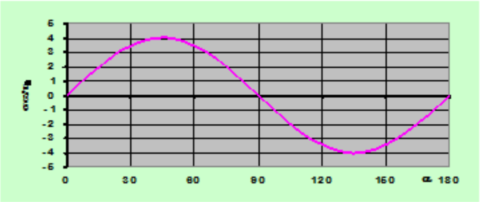
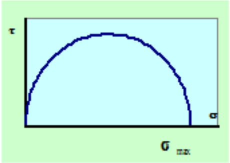
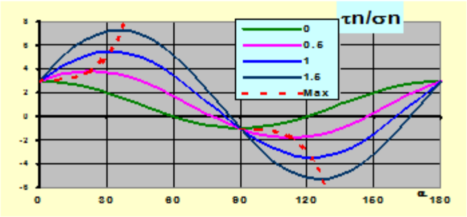
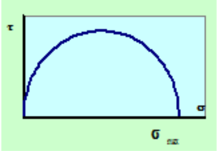
Stress type	Nominal stress tensor	Uniaxial stress distribution around the edge	Mohr's circle diagram
Tension	$\begin{bmatrix}\sigma_n & 0\\ 0 & 0\end{bmatrix}$	$\sigma_\alpha = \sigma_n \gamma_B / 3\,[1+2\cos(2\alpha)]$  	 $\gamma_B = \sigma_{max}/\sigma_n$ for $\alpha = k\pi$
Shear	$\begin{bmatrix}0 & \tau_n\\ \tau_n & 0\end{bmatrix}$	$\sigma_\alpha = \gamma_T\,\tau_n \sin(2\alpha)$  	 $\gamma_T = \sigma_{max}/\tau_n$ for $\alpha = \frac{\pi}{4} + k\frac{\pi}{2}$
Tension + shear	$\begin{bmatrix}\sigma_n & \tau_n\\ \tau_n & 0\end{bmatrix}$	$\sigma_\alpha = \frac{\gamma_B}{3}\sigma_n\left\{1+2\left[\cos(2\alpha)+\frac{3}{2}\frac{\gamma_T}{\gamma_B}\frac{\tau_n}{\sigma_n}\sin(2\alpha)\right]\right\}$  	 $\sigma_{max} = \frac{\gamma_B}{3}\sigma_n\left[1+2\sqrt{1+\frac{9}{4}\left(\frac{\gamma_T}{\gamma_B}\frac{\tau_n}{\sigma_n}\right)^2}\right]$ for $\alpha = \frac{1}{2}\mathrm{tg}^{-1}\left(\frac{3\gamma_T\tau_n}{2\gamma_B\sigma_n}\right)$

Figure 1.3.8 Stress concentration factors and stress distribution at the edges of oil drillings

3.5 Calculation of alternating stresses due to bending moments and radial forces – assumptions

3.5.1 The calculation is based on a statically determined system, composed of a single crankthrow supported in the centre of adjacent main journals and subject to gas and inertia forces. The bending length is taken as the length between the two main bearing midpoints (distance L_3, *see Figure 1.3.9 Bending moment and shear force for in-line engine crankthrows and Figure 1.3.10 Bending moment and shear force for V engine crankthrows*).

3.5.2 The bending moments, M_{BR} and M_{BT}, are calculated in the relevant section based on triangular bending moment diagrams due to the radial component F_R and tangential component F_T of the connecting-rod force, respectively (*see Figure 1.3.9 Bending moment and shear force for in-line engine crankthrows*). For crankthrows with two connecting-rods acting upon one crankpin the relevant bending moments are obtained by superposition of the two triangular bending moment diagrams according to phase (*see Figure 1.3.10 Bending moment and shear force for V engine crankthrows*).

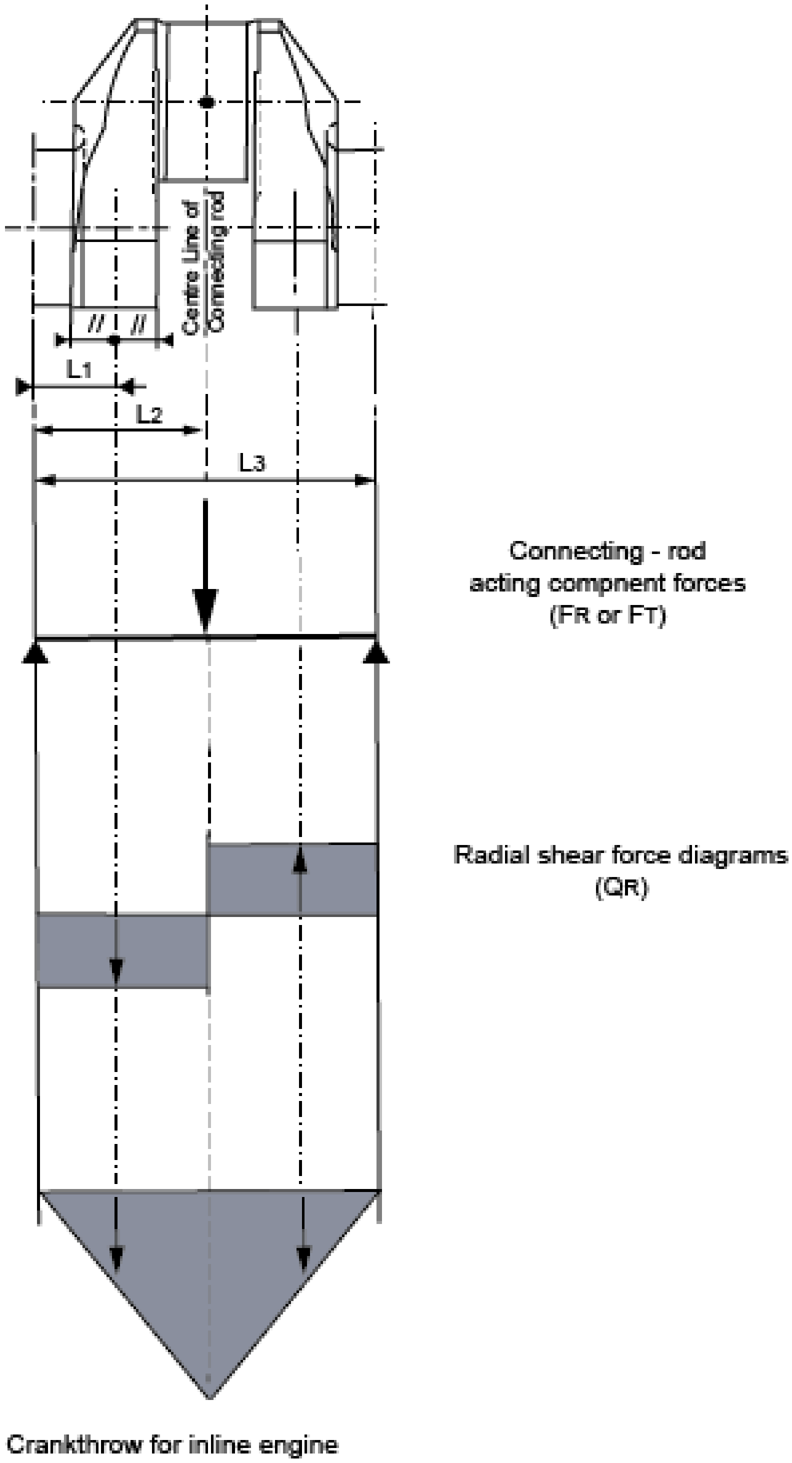

Centre Line of Connecting rod
L1
L2
L3
Connecting - rod acting compnent forces (F_R or F_T)
Radial shear force diagrams (Q_R)
Crankthrow for inline engine

Figure 1.3.9 Bending moment and shear force for in-line engine crankthrows

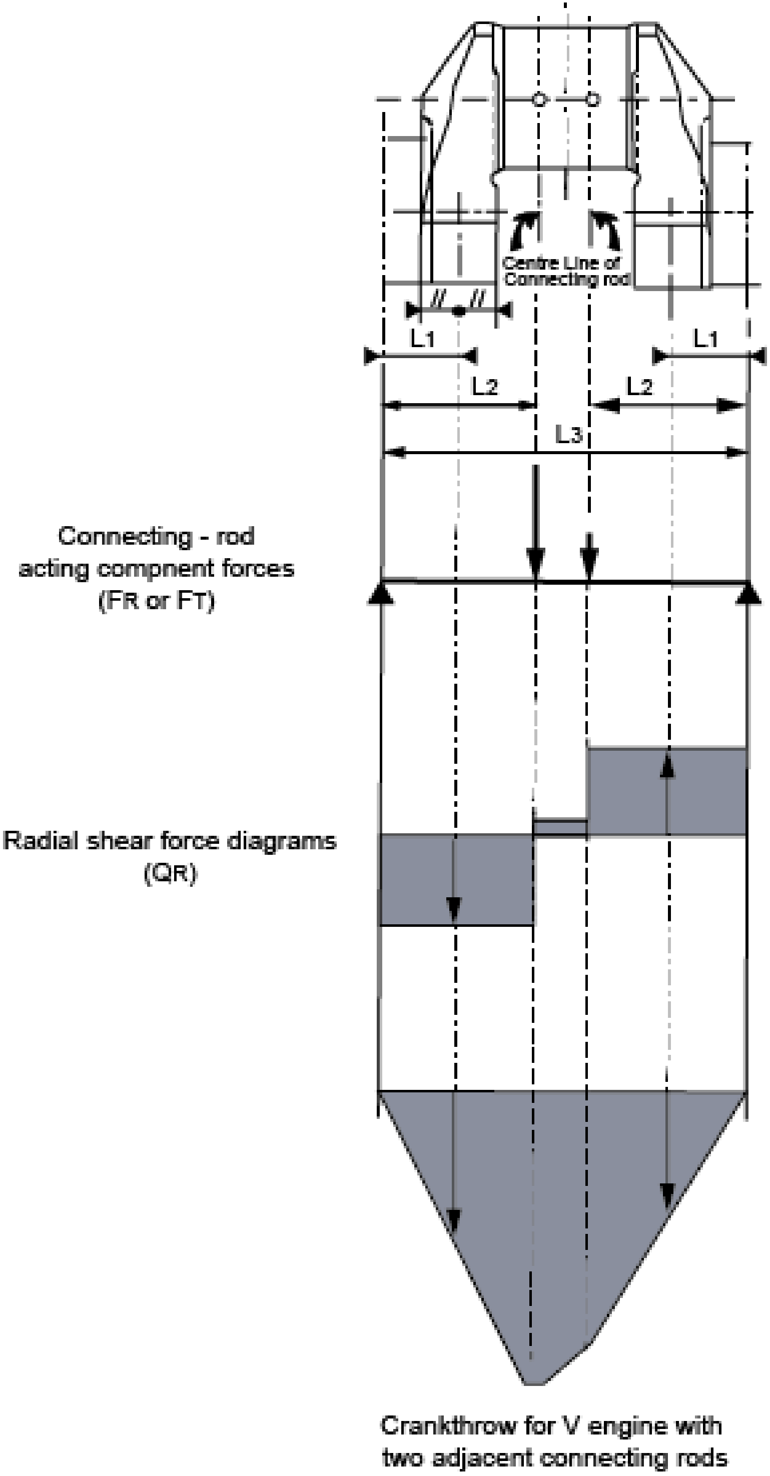

Centre Line of Connecting rod
L1
L1
L2
L2
L3
Connecting - rod acting compnent forces (FR or FT)
Radial shear force diagrams (QR)
Crankthrow for V engine with two adjacent connecting rods

Figure 1.3.10 Bending moment and shear force for V engine crankthrows

3.5.3 The bending moment M_{BRF} and the radial force Q_{RF} are taken as acting in the centre of the solid web (distance L_1) and are derived from the radial component of the connecting-rod force. The alternating bending and compressive stresses due to bending moments and radial forces are to be related to the cross-section of the crankweb. This reference section results from the web thickness W and the web width B (*see Figure 1.3.3 Crank dimensions for overlapped crankshaft* and *Figure 1.3.4 Crank dimensions for crankshaft without overlap*). Mean stresses are neglected.

3.5.4 The two relevant bending moments for bending acting on the outlet of crankpin oil bores are taken in the crankpin cross-section through the oil bore. *See Figure 1.3.9 Bending moment and shear force for in-line engine crankthrows and Figure 1.3.10 Bending moment and shear force for V engine crankthrows*. M_{BRO} is the bending moment of the radial component of the connecting-rod force and M_{BTO} is the bending moment of the tangential component of the connecting-rod force. The alternating stresses due to these bending moments are to be related to the cross-sectional area of the axially bored crankpin. Mean bending stresses are neglected.

3.6 Calculation of bending stresses

3.6.1 The radial and tangential forces due to gas and inertia loads acting upon the crankpin at each connecting-rod position are to be calculated over one working cycle. Using the forces calculated over one working cycle and taking into account of the distance from the main bearing midpoint, the time curve of the bending moments, M_{BRF}, M_{BRO} and M_{BTO}, and radial forces, Q_{RF} ,as defined in *Vol 2, Pt 2, Ch 1, 3.5 Calculation of alternating stresses due to bending moments and radial forces – assumptions 3.5.2* and *Vol 2, Pt 2, Ch 1, 3.5 Calculation of alternating stresses due to bending moments and radial forces – assumptions 3.5.3* are then calculated.

3.6.2 Nominal bending stresses are referred to the web bending modulus.

3.6.3 In case of V-type engines, the bending moments – progressively calculated from the gas and inertia forces – of the two cylinders acting on one crankthrow are superposed according to phase. Different designs (forked connecting-rod, articulated-type connecting-rod or adjacent connecting-rods) shall be taken into account.

3.6.4 Where there are cranks of different geometrical configurations in one crankshaft, the calculation is to cover all crank variants.

3.6.5 The decisive alternating values will then be calculated according to:

$$X_{\mathrm{N}} = \pm\frac{1}{2}\left(X_{\mathrm{max}} - X_{\mathrm{min}}\right)$$

where

X_{N} is considered as alternating force, moment or stress

X_{max} is maximum value within one working cycle

X_{min} is minimum value within one working cycle

3.6.6 Nominal alternating bending and compressive stresses in web cross-section are calculated as follows:

$$\sigma_{\mathrm{BFN}} = \pm\frac{M_{\mathrm{BRFN}}}{W_{\mathrm{eqw}}} 10^{3} K_{\mathrm{e}} \text{ N/mm}^{2}$$

$$\sigma_{\mathrm{QFN}} = \pm\frac{Q_{\mathrm{RFN}}}{F} K_{\mathrm{e}} \text{ N/mm}^{2}$$

where

$$M_{\mathrm{BRFN}} = \pm\frac{1}{2}\left(M_{\mathrm{BRF}\,\mathrm{max}} - M_{\mathrm{BRF}\,\mathrm{min}}\right) \text{ Nm}$$

$$W_{\mathrm{eqw}} = \frac{BW^{\mathrm{z}}}{6} \text{ mm}^{3}$$

K_{e} = 0,8 for crosshead engines
= 1,0 for trunk piston engines

$$Q_{\mathrm{RFN}} = \pm\frac{1}{2}\left(Q_{\mathrm{RFmax}} - Q_{\mathrm{RFmin}}\right) \text{ Nm}$$

F = BW mm^{2}

3.6.7 Nominal alternating bending stress in the outlet of the crankpin oil bore is calculated as follows:

$$\sigma_{\mathrm{BON}} = \pm\frac{M_{\mathrm{BON}}}{W_{\mathrm{e}}} 10^{3} \text{ N/mm}^{2}$$

where

M_{BON} is taken as the ½ range value $M_{\mathrm{BON}} = \pm \frac{1}{2} (M_{\mathrm{BOmax}} - M_{\mathrm{BOmin}})$
and
$M_{BO} = (M_{\mathrm{BTO}} \cos\psi + M_{\mathrm{BRO}} \sin\psi)$, ψ = angular position in degrees, *see Figure 1.3.5 Crankpin section through the oil bore*
M_{BRO} = bending moment of the radial component of the connecting-rod force

M_{BTO} = bending moment of the tangential component of the connecting-rod force

$$W_{\mathrm{e}} = \frac{\pi}{32}\left(\frac{D^{4} - D_{\mathrm{BH}}{}^{4}}{D}\right) \text{ mm}^{3}$$

3.6.8 Alternating bending stresses for the crankpin fillet and journal fillet are calculated as follows:
(a) For the crankpin fillet:

$$\sigma_{\mathrm{BH}} = \pm\left(\alpha_{\mathrm{b}}\sigma_{\mathrm{BFN}}\right) \text{ N/mm}^{2}$$

where

α_B is calculated according to *Vol 2, Pt 2, Ch 1, 3.8 Stress concentration factors 3.8.6 (a)*

(b) For the journal fillet:

$\sigma_{BG} = \left(\beta_B \sigma_{BFN} + \beta_Q \sigma_{QFN}\right)$ N/mm^2

where

β_B is calculated according to *Vol 2, Pt 2, Ch 1, 3.8 Stress concentration factors 3.8.7 (a)*

β_Q is calculated according to *Vol 2, Pt 2, Ch 1, 3.8 Stress concentration factors 3.8.7 (b)*

3.6.9 Alternating bending stresses for the outlet of crankpin oil bore are calculated as follows:

$\sigma BO = \pm\left(\gamma_B \sigma_{BON}\right)$ N/mm^2

where

γ_B is calculated according to *Vol 2, Pt 2, Ch 1, 3.8 Stress concentration factors 3.8.8 (a)*

3.7 Calculation of torsional stresses

3.7.1 The nominal alternating torsional stress, τ_n, is to be taken into consideration. The value is to be derived from forced-damped vibration calculations of the complete dynamic system. Alternative methods will be given consideration. The engine designer is to advise the maximum level of alternating vibratory stress that is permitted.

3.7.2 τ_a or τ_n (as applicable) is to be applied as a limiting value for the torsional vibration assessment required by *Vol 2, Pt 5, Ch 1, Torsional Vibration*.

3.7.3 Nominal alternating torsional stress is calculated as follows:

$\tau_n = \pm \frac{M_{TN}}{W_p} 10^3$ N/mm^2

where

$M_{TN} = \pm\frac{1}{2}(M_{Tmax} - M_{Tmin})$ Nm

$W_p = \frac{\pi}{16}\left(\frac{D^4 - D_{BH}{}^4}{D}\right)$ mm^3 for the crankpin, or $W_p = \frac{\pi}{16}\left(\frac{D_G{}^4 - D_{BG}{}^4}{D_G}\right)$ mm^3 for the journal

τ_N is to be ascertained from assessment of the torsional vibration calculations where the maximum and minimum torques are determined for every mass point of the complete dynamic system and for the entire speed range by means of a harmonic synthesis of the forced vibrations from the first order up to and including the 15th order for 2-stroke cycle engines and from the 0,5th order up to and including the 12th order for 4-stroke cycle engines. Whilst doing so, allowance must be made for the damping that exists in the system and for unfavourable conditions (misfiring in one of the cylinders when no combustion occurs but only compression cycle). The speed step calculation shall be selected in such a way that any resonance found in the operational speed range of the engine shall be detected.

3.7.4 For the purpose of the crankshaft assessment, the nominal alternating torsional stress considered in calculations is to be the highest calculated value, according to the method described in *Vol 2, Pt 2, Ch 1, 3.7 Calculation of torsional stress 3.7.3*, occurring at the most torsionally loaded mass point of the crankshaft system.

3.7.5 The approval of the crankshaft will be based on the installation having the largest nominal alternating torsional stress (but not exceeding the maximum figure specified by the engine manufacturer). For each installation it is to be ensured by calculation that the maximum approved nominal alternating torsional stress is not exceeded. *See Vol 2, Pt 5, Ch 1 Torsional Vibration.*

3.7.6 Alternating torsional stresses for the crankpin fillet, the journal fillet and the outlet of the crankpin oil bore are calculated as follows.

(a) Maximum alternating torsional stress in crankpin fillet:

$\tau_H = \pm\left(\alpha_T \tau_N\right)$ N/mm^2

where

α_T is calculated according to *Vol 2, Pt 2, Ch 1, 3.8 Stress concentration factors 3.8.6 (b)*

(b) Maximum alternating torsional stress in the journal fillet (not applicable to semi-built crankshafts):

$\tau_G = \pm\left(\beta_T \tau_N\right)$ N/mm^2

where

β_T is calculated according to *Vol 2, Pt 2, Ch 1, 3.8 Stress concentration factors 3.8.7 (c)*

(c) Maximum alternating torsional stress in the outlet of the crankpin oil bore:

$\sigma_{TO} = \pm\left(\gamma_T \tau_N\right)$ N/mm^2

where

γ_T is calculated according to *Vol 2, Pt 2, Ch 1, 3.8 Stress concentration factors 3.8.8 (b).*

3.8 Stress concentration factors

3.8.1 Stress concentration factors (SCF) are to be calculated using the analytical formulae outlined in this Section.

3.8.2 Crankshaft variables to be used in calculating the geometric stress concentration~~s~~ factors are shown in *Table 1.3.1 Crankshaft variables for SCF calculation*, their limits of applicability are shown in *Table 1.3.2 Crankshaft variable boundaries for analytical SCF calculation*.

3.8.3 Where the geometry of the crankshaft is outside the boundaries (*see Table 1.3.2 Crankshaft variable boundaries for analytical SCF calculation*) of the analytical SCF the calculation method detailed in Chapter 1 of LR *Guidance Notes for Crankshaft SCF Calculation using Finite Element Method* may be undertaken.

3.8.4 Where reliable experimental measurements and/or calculations are available, which can allow direct assessment of SCF, these can be used. The relevant documents and their analysis are to be submitted for consideration in order to demonstrate their equivalence. This is always to be performed when dimensions are outside the boundaries shown in *Table 1.3.2 Crankshaft variable boundaries for analytical SCF calculation*.

3.8.5 Chapters 1 and 3 of LR *Guidance Notes for Crankshaft SCF Calculation using Finite Element Method* describe how finite element (FE) analyses can be used for the calculation of the SCF. Care needs to be taken to avoid mixing equivalent (von Mises) stresses and principal stresses.

Table 1.3.1 Crankshaft variables for SCF calculation

Variable	Function
r	$= R_H/D$ for crankpin fillet $= R_G/D$ for journal fillet
s	$= S/D$
w	$= W/D$ crankshafts with overlap $= W_{red}/D$ crankshafts without overlap
b	$= B/D$
d_o	$= D_O/D$
d_G	$= D_{BG}/D$
d_H	$= D_{BH}/D$
t_H	$= T_H/D$
t_G	$= T_G/D$

Table 1.3.2 Crankshaft variable boundaries for analytical SCF calculation

Lower bound	Variable	Upper bound
	s	≤ 0,5
0,2 ≤	w	≤ 0,8
1,1 ≤	b	≤ 2,2
0,03 ≤	r	≤ 0,13
0 ≤	d_G	≤ 0,8
0 ≤	d_H	≤ 0,8
0 ≤	d_o	≤ 0,2
Notes Low range of *s* can be extended down to large negative values provided that: • If calculated *f*(recess) < 1 then the factor *f*(recess) is not to be considered (*f*(recess) = 1) • If *s* < –0,5 then *f*(*s*,*w*) and *f*(*r*,*s*) are to be evaluated replacing actual value of *s* by –0,5.		

3.8.6 Crankpin SCF are calculated as follows:

(a) Bending

$\alpha_B = 2{,}6914 f(s,w).f(w).f(b).f(r).f(d_G).f(d_H).f(\text{recess})$

where

$f(s,w) = -4{,}1883 + 29{,}2004w - 77{,}5925w^2 + 91{,}9454w^3 - 40{,}0416w^4 + (1-s)(9{,}5440 - 58{,}3480w + 159{,}3415w^2 - 192{,}5846w^3 + 85{,}2916w^4) + (1-s)^2(-3{,}8399 + 25{,}0444w - 70{,}5571w^2 + 87{,}0328w^3 - 39{,}1832w^4)$

$f(w) = 2{,}1790w^{0{,}7171}$

$f(b) = 0{,}684 - 0{,}0077b + 0{,}1473b^2$

$f(r) = 0{,}2081r^{(-0{,}5231)}$

$f(d_G) = 0{,}9993 + 0{,}27d_G - 1{,}0211d_G^2 + 0{,}5306d_G^3$

$f(d_H) = 0{,}9978 + 0{,}3145d_H - 1{,}5241d_H^2 + 2{,}4147d_H^3$

$f(\text{recess}) = 1 + (t_H + t_G)(1{,}8 + 3{,}2s)$

(b) Torsion

$\alpha_T = 0{,}8f(r,s).f(b).f(w)$

where

$f(r,s) = r^{(-0{,}322 + 0{,}1015\,(1-s))}$

$f(b) = 7{,}8955 - 10{,}654b + 5{,}3482b^2 - 0{,}857b^3 f(w) = w^{(-0{,}145)}$

3.8.7 Journal fillet SCF are calculated as follows(not applicable to semi-built crankshafts):

(a) Bending

$\beta_B = 2{,}7146 f_B(s,w) . f_B(w) . f_B(b) . f_B(r) . f_B(d_G) . f_B(d_H) . f(\text{recess})$

where

$f_B(s,w) = -1{,}7625 + 2{,}9821w - 1{,}5276w^2 + (1 - s)(5{,}1169 - 5{,}8089w + 3{,}1391w^2) + (1 - s)^2(-2{,}1567 + 2{,}3297w - 1{,}2952w^2)$

$f_B(w) = 2{,}2422w^{0{,}7548}$

$f_B(b) = 0{,}5616 + 0{,}1197b + 0{,}1176b^2$

$f_B(r) = 0{,}1908r^{(-0{,}5568)}$

$f_B(d_G) = 1{,}0012 - 0{,}6441d_G + 1{,}2265d_G^2$

$f_B(d_H) = 1{,}0022 - 0{,}1903d_H + 0{,}0073d_H^2$

$f(\text{recess}) = 1 + (t_H + t_G)(1{,}8 + 3{,}2s)$

(b) Compression due to the radial force:

$\beta_Q = 3{,}0128 f_Q(s) . f_Q(w) . f_Q(b) . f_Q(r) . f_Q(d_H) . f(\text{recess})$

where

$f_Q(s) = 0{,}4368 + 2{,}1630(1 - s) - 1{,}5212(1 - s)^2$

$f_Q(w) = \frac{w}{0{,}0637 + 0{,}9369w}$

$f_Q(b) = b - 0{,}5$

$f_Q(r) = 0{,}5331r^{(-0{,}2038)}$

$f_Q(d_H) = 0{,}9937 - 1{,}1949d_H + 1{,}7373d_H^2$

$f(\text{recess}) = 1 + (t_H + t_G)(1{,}8 + 3{,}2s)$

(c) Torsion:

$\beta_T = \alpha_T$ if the diameters and fillet radii of crankpin and journal are the same, or

$\beta_T = 0{,}8f(r,s) . f(b) . f(w)$ if crankpin and journal diameters and/or radii are of different sizes

where

$f(r,s)$, $f(b)$ and $f(w)$ are to be determined in accordance with *Vol 2, Pt 2, Ch 1, 3.8 Stress concentration factors 3.8.6 (b)*, however, the radius of the journal fillet is to be related to the journal diameter: $r = \frac{R_G}{D_G}$

3.8.8 Crankpin oil bore SCF for radially drilled oil holes are calculated as follows:

(a) Bending

$\gamma_B = 3 - 5{,}88d_o + 34{,}6d_o^2$

(b) Torsion

$\gamma_T = 4 - 6d_o + 30d_o^2$

3.9 Additional bending stress

3.9.1 In addition to the alternating bending stresses in fillets (*see Vol 2, Pt 2, Ch 1, 3.6 Calculation of bending stresses 3.6.8*) further bending stresses due to misalignment and bedplate deformation as well as due to axial and bending vibrations are to be considered by applying α_{add} as given by *Table 1.3.3 Additional bending stresses*.

Table 1.3.3 Additional bending stresses

Type of engine	σ_{add}
Crosshead engines	± 30 N/mm² (*see* Note 1)
Trunk piston engines	± 10 N/mm²
Note 1. The additional stress of ±30 N/mm² is composed of two components: (a) an additional stress of ±20 N/mm² resulting from axial vibration (b) an additional stress of ±10 N/mm² resulting from misalignment/bedplate deformation	

3.9.2 It is recommended that a value of ±20 N/mm² be used for the axial vibration component for assessment purposes where axial vibration calculation results of the complete dynamic system (engine/shafting/gearing/propeller) are not available. Where axial vibration calculation results of the complete dynamic system are available, the calculated figures can be used instead.

3.10 Equivalent alternating stress

3.10.1 In the fillets, bending and torsion lead to two different biaxial stress fields which can be represented by a von Mises equivalent stress with the additional assumptions that bending and torsion stresses are time phased and the corresponding peak values occur at the same location (*see Figure 1.3.7 Stress concentration factors in crankshaft fillets*). As a result the equivalent alternating stress is to be calculated for the crankpin fillet as well as for the journal fillet by using the von Mises criterion.

3.10.2 At the oil hole outlet, bending and torsion lead to two different stress fields which can be represented by an equivalent principal stress equal to the maximum of principal stress resulting from combination of these two stress fields with the assumption that bending and torsion are time phased (*see Figure 1.3.8 Stress concentration factors and stress distribution at the edges of oil drillings*).

3.10.3 The above two different ways of equivalent stress evaluation both lead to stresses which can be compared to the same fatigue strength value of crankshaft assessed according to the von Mises criterion.

3.10.4 Equivalent alternating stress, σ_v, is defined as:
(a) For the crankpin fillet:

$$\sigma_v = \pm\sqrt{(\sigma_{BG}+\sigma_{add})^2+3\tau_G{}^2} \text{ N/mm}^2$$

(b) For the journal fillet:

$$\sigma_v = \pm\sqrt{(\sigma_{BH}+\sigma_{add})^2+3\tau_H{}^2} \text{ N/mm}^2$$

(c) For the outlet of crankpin oil bore:

$$\sigma_v = \pm\frac{1}{3}\sigma_{BO}\left[1+2\sqrt{1+\frac{9}{4}\left(\frac{\sigma_{TO}}{\sigma_{BO}}\right)^2}\right] \text{ N/mm}^2$$

3.11 Fatigue strength

3.11.1 The fatigue strength is to be understood as that value of equivalent alternating stress (Von Mises) which a crankshaft can permanently withstand at the most highly stressed points. The fatigue strength can be evaluated by means of the following formulae.
(a) Related to the crankpin diameter:

$$\sigma_{DW} = \pm K(0{,}42\sigma_B+39{,}3)\left[0{,}264+1{,}073D^{-0{,}2}+\frac{795-\sigma_B}{4900}+\frac{196}{\sigma_E}\sqrt{\frac{1}{R_x}}\right] \text{ N/mm}^2$$

with
$R_X = R_H$ in the fillet area
$R_X = D_o/2$ in the oil bore area

(b) Related to the journal diameter:

$$\sigma_{DW} = \pm K(0{,}42\sigma_B+39{,}3)\left[0{,}264+1{,}073D_G{}^{-0{,}2}+\frac{795-\sigma_B}{4900}+\frac{196}{\sigma_E}\sqrt{\frac{1}{R_x}}\right] \text{ N/mm}^2$$

where
$K = K_1K_2$
K_1 = fatigue endurance factor appropriate to the manufacturing process
= 1,05 for continuous grain flow forged or drop-forged crankshafts
= 1,0 for free form forged crankshafts (without continuous grain flow)
= 0,93 for cast steel crankshafts with cold rolling treatment in fillet area manufactured by companies using a LR approved cold rolling process

K_2 = fatigue enhancement factor for surface treatment. These treatments are to be applied to the fillet radii

A value for K_2 will be assigned upon application by the engine designers. Full details of the process, together with the results of full scale fatigue tests will be required to be submitted for consideration *See LR Guidance note - Guidance for the evaluation of Crankshaft Fatigue Tests*. Alternatively, the following values may be taken (surface hardened zone to include fillet radii):

K_2 = 1,15 for induction hardened
= 1,25 for nitrided

Where a value of K_1 or K_2 greater than unity is to be applied then details of the manufacturing process are to be submitted. An enhanced K_1 factor will be considered, subject to special approval of the manufacturing specification. *See Materials and Qualification Procedures for Ships, Book E, Procedure MQPS 5-2*.

3.11.2 The formulae in *Vol 2, Pt 2, Ch 1, 3.11 Fatigue strength 3.11.1* are subject to geometry limits. The junction of the oil hole with the crankpin or main journal surface is to be formed with an adequate radius and smooth surface finish down to a minimum depth equal to 1,5 times the oil bore diameter and for calculation purposes R_H, R_G or R_X are to be taken as not less than 2 mm.

3.11.3 Fatigue strength calculations or alternatively fatigue test results determined by experiment based either on full size crankthrow (or crankshaft) or on specimens taken from a full size crankthrow may be required to demonstrate acceptability. The experimental procedure for fatigue evaluation of specimens and fatigue strength of crankshaft assessment are to be submitted for approval by LR. The procedure is to include as a minimum: method, type of specimens, number of specimens (or crankthrows), number of tests, survival probability, and confidence number. *See also* LR *Guidance for the Evaluation of Crankshaft Fatigue Tests.*

3.11.4 When journal diameter is equal or larger than the crankpin diameter, the outlets of main journal oil bores are to be formed in a similar way to the crankpin oil bores, otherwise separate fatigue strength calculations or, alternatively, fatigue test results may be required.

3.11.5 Only surface treatment processes approved by LR are permitted. Guidance for calculation of surface treated fillets and oil bore outlets is presented in Chapter 2 of the LR *Guidance Notes for Crankshaft SCF Calculation using Finite Element Method*.

3.12 Acceptability criteria

3.12.1 The sufficient dimensioning of a crankshaft is confirmed by a comparison of the equivalent alternating stress and the fatigue strength. The acceptability factor, Q, is to be greater than or equal to 1,15 for the crankpin fillet, the journal fillet, the outlet of crankpin oil bore:

$$Q = \frac{\sigma_{\mathrm{DW}}}{\sigma_{\mathrm{V}}}$$

3.13 Shrink fit of semi-built crankshafts

3.13.1 The following formulae are applicable to crankshafts assembled by shrinking main journals into the crankwebs, *see also Figure 1.3.6 Crankthrow of semi-built crankshaft*.

3.13.2 In general, the radius of transition, R_{G}, between the main journal diameter, D_{G}, and the shrink diameter, D_{S}, is to be not less than $0{,}015D_{\mathrm{G}}$ or $0{,}5(D_{\mathrm{S}} - D_{\mathrm{G}})$ where the greater value is to be considered.

3.13.3 Deviations from these parameters will be specially considered.

3.13.4 The maximum permissible internal diameter in the journal pin is to be calculated in accordance with the following formula, this condition serves to avoid plasticity in the hole of the journal pin:

$$D_{\mathrm{BG}} = D_{\mathrm{S}} \sqrt{1 - \frac{4000 S_{\mathrm{R}} M_{\max}}{\mu \pi D_{\mathrm{S}}^{2} L_{\mathrm{S}} \sigma_{\mathrm{SP}}}} \text{ mm}$$

where
S_{R} = safety factor against slipping; however, a value not less than 2 is to be taken unless documented by experiments.
$M_{\max}$ = absolute maximum value of the torque M_{Tmax} in accordance with *Vol 2, Pt 2, Ch 1, 3.7 Calculation of torsional stresses 3.7.3*, in Nm
μ = coefficient for static friction; however, a value not greater than 0,2 is to be taken unless documented by experiments.

3.13.5 The actual oversize Z of the shrink fit must be within the limits $Z_{\min}$ and $Z_{\max}$ calculated in accordance *Vol 2, Pt 2, Ch 1, 3.13 Shrink fit of semi-built crankshafts 3.13.7* and *Vol 2, Pt 2, Ch 1, 3.13 Shrink fit of semi-built crankshafts 3.13.8.* When *Vol 2, Pt 2, Ch 1, 3.13 Shrink fit of semi-built crankshafts 3.13.5* cannot be complied with, then the calculated values of $Z_{\min}$ and $Z_{\max}$ are not applicable due to multizone-plasticity problems. In such cases $Z_{\min}$ and $Z_{\max}$ are to be established from FEM calculations.

3.13.6 The minimum required diametral Interference is to be taken as the greater of**:**

$$Z\mathrm{min} \geq \frac{\sigma_{\mathrm{SW}} D_{\mathrm{S}}}{E_{\mathrm{m}}} \text{ mm}$$

and

$$Z_{\min} \geq \frac{4000}{\mu \pi} \frac{S_{\mathrm{R}} M_{\max}}{E_{\mathrm{m}} D_{\mathrm{s}} L_{\mathrm{s}}} \frac{1 - Q_{\mathrm{A}}^{2} Q_{\mathrm{s}}^{2}}{\left(1 - Q_{\mathrm{A}}^{2}\right)\left(1 - Q_{\mathrm{s}}^{2}\right)} \text{ mm}$$

where

Q_{A} = web ratio, $Q_{\mathrm{A}} = \dfrac{D_{\mathrm{S}}}{D_{\mathrm{A}}}$

Q_{S} = shaft ratio, $Q_{\mathrm{S}} = \dfrac{D_{\mathrm{BG}}}{D_{\mathrm{S}}}$

3.13.7 The maximum diametral interference is not to be greater than:

$$Z_{\max} \leq D_{\mathrm{s}} \left(\frac{Q_{\mathrm{SW}}}{E_{\mathrm{m}}} + \frac{0{,}8}{1000} \right) \text{mm}$$

This condition serves to restrict the shrinkage induced mean stress in the fillet.

3.13.8 Reference marks are to be provided on the outer junction of the crankwebs with the journals.

■ *Section ~~13~~ 4*
Electronically controlled engines

~~13.1~~ 4.1 ~~Scope~~ General

~~13.1.1~~ 4.1.1 The requirements of this Section are applicable to engines for propulsion, auxiliary or emergency~~, *see Vol 2, Pt 2, Ch 1, 13.5 Emergency engines*,~~ power purposes with programmable electronic systems implemented and used to control fuel injection timing and duration, and which may also control combustion air or exhaust systems. The requirements of this Section also apply to programmable electronic systems used to control other functions (e.g. starting and control air, cylinder lubrication, etc.) where essential for the operation of the engine.

Existing paragraphs 13.1.2 to 13.1.6 have been renumbered 4.1.2 to 4.1.6.

~~13.2~~ 4.2 Risk Assessment (RA)

~~13.2.1~~ 4.2.1 A Risk Assessment (RA) is to be carried out in accordance with the requirements of *Vol 2, Pt 1, Ch 3, 18 Risk Assessment (RA)*, and to demonstrate compliance with the applicable requirements of this sub-Section appropriate to the engine application. The analysis is to be a risk-based consideration of engine operation and ship and personnel safety, and is to demonstrate adequate risk mitigation through fault tolerance and/or reliability in accordance with the specified criteria in *Vol 2, Pt 2, Ch 1, ~~13~~ 4.2 Risk Assessment (RA)~~ 13.2.2~~ 4.2.2* to *Vol 2, Pt 2, Ch 1, 4.2 Risk Assessment (RA) 4.2.4*, relevant to the engine application.

~~13.2.2~~ 4.2.2 For ships with a single main propulsion engine, a RA of system reliability~~, in accordance with *Vol 2, Pt 1, Ch 3, 18 Risk Assessment (RA)*,~~ is to be carried out and is to demonstrate that an electronic control system failure:

(a) will not result in the loss of the ability to provide the services essential for the operation of the engine, *see Vol 2, Pt 9, Ch 7, 4.5 Control systems, general requirements 4.5.7* and *Vol 2, Pt 9, Ch 8, 5.4 Additional requirements for Mobility category and safety critical systems 5.4.2*;

will not affect the normal operation of the services essential for the operation of the engine other than those services dependent upon the failed part, *see Vol 2, Pt 9, Ch 8, 5.5 Additional requirements for integrated systems 5.5.4* and *Vol 2, Pt 9, Ch 8, 5.5 Additional requirements for integrated systems 5.5.5*; and

will not leave either the engine, or any equipment or machinery associated with the engine, or the ship in an unsafe condition, *see Vol 2, Pt 9, Ch 7, 4.3 Alarm systems, general requirements 4.3.15, Vol 2, Pt 9, Ch 7, 4.4 Safety systems, general requirements 4.4.5, Vol 2, Pt 9, Ch 7, 4.5 Control systems, general requirements 4.5.4, Vol 2, Pt 9, Ch 8, 5.1 General requirements 5.1.3, Vol 2, Pt 9, Ch 8, 5.1 General requirements 5.1.4* and *Vol 2, Pt 9, Ch 8, 5.5 Additional requirements for integrated systems 5.5.5*.

~~13.2.3~~ 4.2.3 A RA is to be carried out for:

(a) main engines on ships with multiple main engines or other means of providing propulsion power; and/or
(b) auxiliary engines intended to drive electric generators forming the ship's main source of electrical power or otherwise providing power for essential services.

The RA is to demonstrate that adequate hazard mitigation has been incorporated in electronically controlled engine systems or the overall ship installation, with respect to personnel safety and providing propulsion power and/or power for essential services for the safety of the ship. Arrangements satisfying the criteria of *Vol 2, Pt 2, Ch 1, ~~13.2~~ 4.2 Risk Assessment (RA) ~~13.2.2~~ 4.2.2* will also be acceptable.

~~13.2.4~~ 4.2.4 For engines for emergency power purposes, a RA is to be carried out to demonstrate that the design incorporates adequate hazard mitigation~~,~~ such that the likelihood of an electronic engine system failure resulting in the loss of the ability to provide emergency power when required has been reduced to a level considered acceptable by LR~~,~~ and that means are provided to detect failures and permit personnel to restore engine availability to operate on demand. Failures which would result in engine failure and/or damage or loss of availability are to be identified and the report is to include documentation of:

(a) component reliability evidence;
(b) failure detection and alarms; and
(c) failure response required to restore engine availability and maintain personnel safety.

~~13.2.5~~ 4.2.5 The RA report is to:

(a) Identify the standards used for analysis and system design.
(b) Identify the engine, its purpose and the associated objectives of the analysis.
(c) Identify any assumptions made in the analysis.
(d) Identify the equipment, system or sub-system~~,~~ and the mode of operation ~~and the equipment~~.
(e) Identify potential failure modes and their causes.
(f) Evaluate the local effects (e.g. fuel injection failure) and the effects on the system as a whole (e.g. loss of propulsion power) of each failure mode.
(g) Identify measures for reducing the risks associated with each failure mode (e.g. system design, failure detection and alarms, redundancy, quality control procedures for sourcing, manufacture and testing, etc.).
(h) Identify trials and testing necessary to prove conclusions.

~~13.2.6~~ 4.2.6 In an electronically controlled engine, it is necessary to define the essential services on which the operation of the engine relies, and the control functions, alarm functions and safety functions for the equipment and machinery providing these services. Examples of essential services are:
(a) Starting arrangements.
(b) Fuel supply arrangements.
(c) Lubricating oil arrangements.
(d) Hydraulic oil arrangements.
(e) Cooling arrangements.
(f) Power supply arrangements.

~~13.2.8~~ 4.2.7 At sub-system level, it is acceptable to consider failure of equipment items and their functions, e.g. failure of a pump to produce flow or pressure head. It is not required that the failure of components within that pump be analysed, and failure need only be dealt with as a cause of failure of the pump.

~~13.3~~ 4.3 Control engineering systems

~~13.3.1~~ 4.3.1 Control, alarm, monitoring, safety and programmable electronic systems are to comply with *Vol 2, Pt 9 Electrotechnical Systems* and *Vol 2, Pt 10 Human Factors*, as applicable.

~~13.3.2~~ 4.3.2 The engine control, alarm, monitoring and safety systems are to be configured to comply with the relevant requirements (e.g. operating profile, alarms, shutdowns, etc.) of this Chapter and *Vol 2, Pt 9 Electrotechnical Systems* and *Vol 2, Pt 10 Human Factors* for an engine for main, auxiliary or emergency power purposes. Details of the engine configuration are to be submitted for consideration, *see Vol 2, Pt 2, Ch 1, ~~2.2~~ 1.4 Submission requirements ~~2.2.1~~ 1.4.2*.

~~13.4~~ 4.4 Software

~~13.4.1~~ 4.4.1 Software lifecycle activities are to be carried out in accordance with an acceptable quality management system, *see Vol 2, Pt 9, Ch 8, 5.4 Additional requirements for Mobility category and safety critical systems 5.4.2* and *Vol 2, Pt 9, Ch 8, 5.4 Additional requirements for Mobility category and safety critical systems 5.4.7*.

~~13.4.2~~ 4.4.2 Appropriate safety related processes, methods, techniques and tools are to be applied to software development and maintenance by the engine packager or system integrator. Selection and application of techniques and measures in accordance with Annex A of IEC 61508-3, *Functional safety of electrical/electronic/programmable electronic systems: Software requirements*, or other relevant standards or codes acceptable to LR, will generally be acceptable.

~~13.4.3~~ 4.4.3 To demonstrate compliance with *Vol 2, Pt 2, Ch 1, ~~13.4~~ 4.4 Software ~~13.4.1~~ 4.4.1* and *Vol 2, Pt 2, Ch 1, ~~13.4~~ 4.4 Software ~~13.4.2~~ 4.4.2*:
(a) software quality plans and safety evidence are to be submitted for consideration, *see Vol 2, Pt 2, Ch 1, ~~2.2~~ 1.4 Submission requirements ~~2.2.2.(b)~~ 1.4.3(b)* and *Vol 2, Pt 2, Ch 1, ~~2.2~~ 1.4 Submission requirements ~~2.2.2.(c)~~ 1.4.3(c);* and
(b) an assessment inspection of the engine packager's or system integrator's completed development is to be carried out by LR. The inspection is to be tailored to verify application of the standards and codes used in software safety assurance accepted by LR.

~~13.5~~ 4.5 Additional requirements for ~~E~~emergency engines for naval vessels

~~13.5.1~~ 4.5.1 Electronically controlled engines will only be accepted for use as emergency engines when the additional requirements of this sub-Section are satisfied.

~~13.5.2 The use of electronically controlled engines for emergency power purposes will only be permitted if specified by the Naval Administration.~~

~~13.5.3~~ 4.5.2 Electrically powered control equipment required for engine starting or operation is to be served by not less than two individual power supplies, one fed from a main switchboard circuit and one from an emergency switchboard circuit provided in accordance with *Vol 2, Pt 2, Ch 1, ~~13.5~~ 4.5 Additional requirements for ~~E~~emergency engines for naval vessels ~~13.5.4~~ 4.5.3* and *Vol 2, Pt 2, Ch 1, ~~13.5~~ 4.5 Additional requirements for ~~E~~emergency engines for naval vessels ~~13.5.5~~ 4.5.4*.

~~13.5.4~~ 4.5.3 Each power supply is to be provided with an Uninterruptible Power System (UPS) in accordance with *Vol 2, Pt 9, Ch 3, 7.3 Uninterruptible power systems* capable of supplying the starting arrangements for three successive starts over a period of at least 30 minutes. A manual supply changeover switch is to be provided.

~~13.5.5~~ 4.5.4 The power supplies are not to pass through a common switchboard or section board and are not to use common feeders, protective devices, control circuits, controlgear assemblies or battery chargers, so that any single fault will not cause the loss of both supplies. Where adequate circuit protection and stored battery and charging capacity exists, the engine starting batteries may be used to provide one supply.

~~13.5.6~~ 4.5.5 Where the proposed arrangement of engine electronic control systems do not incorporate redundancy to satisfy the requirements of *Vol 2, Pt 2, Ch 1, ~~13~~4.2 Risk Assessment (RA) ~~13~~4.2.1*, evidence is to be submitted that demonstrates the arrangements have been assessed and found to comply with IEC 61508, functional safety of electrical/electronic/programmable electronic systems, or a relevant alternative standard. The submissions are to include proposals for LR to verify compliance (reviews, ~~S~~surveys, trials, etc.) with the applicable standard(s).

~~13.2.7~~ 4.5.6 Where emergency engines are used as harbour sets, the system is to comply with the requirements of *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.6*. This function is to be included in the RA.

4.5.7 Emergency engines are required to be immediately available in an emergency and capable of being controlled remotely or automatically.

■ *Section 5*
Construction and welded structures

5.1 Crankcases

5.1.1 Crankcases and their doors are to be of robust construction to withstand anticipated crankcase pressures that may arise during a crankcase explosion taking into account the installation of explosion relief valves required by *Vol 2, Pt 2, Ch 1, ~~6~~ 10 Safety arrangements ~~on engines~~* and ~~T~~the doors are to be securely fastened so that they will not be readily displaced by a crankcase explosion.

5.3 Materials and construction

5.3.1 All welded construction is to be in accordance with the requirements specified in *Ch 13 Requirements for Welded Construction* of the Rules for Materials, using welding procedures and welders that have been qualified in accordance with *Ch 12 Welding Qualifications* of the Rules for Materials.

~~5.3.3 Plates and weld preparations are to be accurately machined or flame-cut to shape. Flame-cut surfaces are to be cleaned by machining or grinding; if the flame-cut surfaces are smooth, wire brushing may be accepted.~~

Existing paragraphs 5.3.4 to 5.3.6 have been renumbered 5.3.3 to 5.3.5.

5.5 Inspection

5.5.2 ~~On completion of welding and stress relief heat treatment, all welds are to be examined.~~ Inspection of welds is to be in accordance with the requirements of *Ch 13, 1.11 Non-destructive examination of welds* of the Rules for Materials.

■ *Section 6*
Turning gear

~~1.5~~ 6.1 ~~Turning gear~~ General requirements

~~1.5.1~~ 6.1.1 Turning gear is to be provided for all engines to facilitate operating and maintenance regimes as required by the manufacturer. ~~Manuals are to be provided and are to comply with the requirements of *Vol 2, Pt 1, Ch 1, 4.6 Through life operation principles 4.6.7*.~~

~~1.5.2~~ 6.1.2 The turning gear for all propulsion engines is to be power-driven and is to be continuously rated at a value to ensure protection to the weakest part of the machinery. Alternative proposals may be made subject to special consideration.

~~1.5.3~~ 6.1.3 The turning gear for auxiliary engines may be hand operated (manual) except where this is not practicable, in which case the provision of *Vol 2, Pt 2, Ch 1, ~~1.5~~ 6.1 ~~Turning gear~~ General requirements ~~1.5.2~~ 6.1.2* is to be complied with.

~~1.5.4~~ 6.1.4 The turning gear for all engines is to be fitted with safety Interlocks which prevent engine operation when engaged see *Vol 2, Pt 1, Ch 3, 4.14 Machinery interlocks*. Indication of engaged/disengaged is to be provided at all start positions. ~~In the case of unattached hand operated turning gear engine operation may be prevented by manual means including the provision of warning devices or notices.~~

Existing paragraphs 1.5.5 to 1.5.7 have been renumbered 6.1.5 to 6.1.7.

■ *Section ~~9~~ 7*
Control and monitoring of main, auxiliary and emergency engines

~~9.1~~ 7.1 General

~~9.1.1~~ 7.1.1 ~~The~~ Control ~~and Monitoring~~ engineering systems are to comply with the requirements of *Vol 2, Pt 9 Electrotechnical Systems*. ~~*See Vol 2, Pt 1, Ch 3, 4 Operating conditions* for requirements for operating conditions.~~

~~9.1.2~~ 7.1.2 Oil mist detection~~,~~ or engine bearing temperature monitors (or ~~alternative for crankcase protection methods~~ equivalent device) ~~are to be provided~~ fitted as required by *Vol 2, Pt 2, Ch 1, 10.8 Oil mist detection 10.8.1* are to operate as follows:
~~(a) When arrangements are fitted to override the automatic shutdown for excessive reduction of the lubricating oil supply pressure.~~
~~(b) For engines of 2,250 kW and above or having cylinders of more than 300 mm bore.~~
~~Note *1.* For trunk piston engines automatic shutdown of the engine is to occur.~~
~~Note *2.* For crosshead engines, automatic slow-down is to occur.~~
~~Note *3.* Where arrangements are made to override the automatic slow-down or shutdown due to high oil mist or bearing temperature, the override is to be independent of other overrides.~~
~~Note *4.* Where the bearing temperature monitoring method is chosen, all bearings in the crankcase are to be monitored where practicable, e.g. main, crankpin, crosshead.~~
~~Note *5.* Where engine bearing temperature monitors or alternative methods are provided for the prevention of the build up of oil mist that may lead to a potentially explosive condition within the crankcase, details are to be submitted for consideration. The submission is to demonstrate that the arrangements are equivalent to those provided by oil mist detection, *see Vol 2, Pt 2, Ch 1, 6.8 Oil mist detection 6.8.14*.~~
(a) For trunk piston engines, automatic shutdown of the engine is to occur when oil mist or high bearing temperature is detected.
(b) For crosshead engines, automatic slow-down is to occur when oil mist or high bearing temperature is detected.
(c) Where arrangements are made to override the automatic slow-down or shutdown due to high oil mist or bearing temperature, the override is to be independent of other overrides.
(d) Where the bearing temperature monitoring method is chosen, all bearings in the crankcase are to be monitored where practicable, e.g. main, crankpin, crosshead.
(e) Where engine bearing temperature monitors or equivalent devices are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase, details are to be submitted for consideration. The submission is to demonstrate that the arrangements are equivalent to those provided by oil mist detection, *see Vol 2, Pt 2, Ch 1, 10.8 Oil mist detection 10.8.15*.

~~9.1.3~~ 7.1.3 All main and auxiliary engines intended for Mobility or Ship Type systems are to be provided with means of indicating the lubricating oil pressure supply to them. Where such engines are of more than 37 kW, audible and visual alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. Further, these alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

Existing sub-Section 9.2 has been renumbered 7.2.

~~9.3~~ 7.3 Auxiliary engine governors

Existing paragraph 9.3.1 has been renumbered 7.3.1.

~~9.3.2~~ 7.3.2 If an engine cannot achieve the requirements of *Vol 2, Pt 2, Ch 1, ~~9.3~~ 7.3 Auxiliary engine governors ~~9.3.1~~ 7.3.1* then the actual load step is to be declared and verified through testing to ensure the requirements specified in *Vol 2, Pt 9, Ch 1, 2.1 Quality of power supplies (QPS)* are satisfied. In cases where a step load equivalent to the rated output of a generator is switched off, a transient speed variation in excess of 10 per cent of the rated speed is acceptable, provided this does not cause the intervention of the overspeed device as required by *Vol 2, Pt 2, Ch 1, 7.5 Overspeed protective devices 7.5.1*.

~~9.3.5~~ 7.3.3 Emergency generator engines are to comply with *Vol 2, Pt 2, Ch 1, ~~9.3~~ 7.3 Auxiliary engine governors ~~9.3.1~~ 7.3.1* except that the initial load required by *Vol 2, Pt 2, Ch 1, ~~9.3~~ 7.3 Auxiliary engine governors ~~9.3.1~~ 7.3.1(b)* is to be not less than the total connected emergency load, or if their total consumer load is applied in steps, the following requirements are to be met:
(a) the total load is supplied within 45 seconds from power failure on the main switchboard;
(b) the maximum step load is declared and demonstrated; and
(c) the power distribution system is designed such that the declared maximum step loading is not exceeded.

~~9.3.6~~ 7.3.4 Compliance of time delays and loading sequence with the requirements of *Vol 2, Pt 2, Ch 1, ~~9.3~~ 7.3 Auxiliary engine governors ~~9.3.4~~* 7.3.5 is to be demonstrated at ship's trials.

~~9.3.4~~ 7.3.5 For alternating current installations, the permanent speed variations of the machines intended for parallel operation are to be equal within a tolerance of ±0.5 per cent. Momentary speed variations with load changes in accordance with *Vol 2, Pt 2, Ch 1, ~~9.3~~ 7.3 Auxiliary engine governors ~~9.3.1~~ 7.3.1* are to return to and remain within one per cent of the final steady state speed. Where there are no stated electrical power supply requirements for a particular installation, this should normally be accomplished within five but in no case more than eight seconds. For quality of power supplies, *see Vol 2, Pt 9, Ch 1, 2.1 Quality of power supplies (QPS)*.

7.4 Additional requirements for auxiliary engine governors for naval vessels

~~9.3.3~~ 7.4.1 The no-load stability of governors on electrical generator engines is to be such as to enable satisfactory paralleling to be achieved.

~~9.4~~ 7.5 Overspeed protective devices

Existing paragraph 9.4.1 has been renumbered 7.5.1.

~~9.4.2~~ 7.5.2 The overspeed protective device, including its driving mechanism, is to be independent of the governor required by *Vol 2, Pt 2, Ch 1,~~ 9.4 Overspeed protective devices~~ 7.2 Main engine governers* or *Vol 2, Pt 2, Ch 1,~~ 9.5 Engine stopping,~~ 7.3 Auxiliary engine governers* and is to be so adjusted that the speed does not exceed that for which the engine and its driven machinery are to be classed by more than 20 per cent for main engines and 15 per cent for auxiliary engines.

~~9.6~~ 7.6 Unattended machinery

~~9.6.1~~ 7.6.1 Where main and auxiliary engines are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms and safety arrangements required by *~~Vol 2, Pt 2, Ch 1, 9.1 General~~ Vol 2, Pt 2, Ch 1, 7.6 Unattended machinery* to *Vol 2, Pt 2, Ch 1, 7.8 Auxiliary engines* as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

Existing paragraphs 9.6.2 and 9.6.3 have been renumbered 7.6.2 and 7.6.3.

~~9.6.4~~ 7.6.4 Where a first stage alarm together with a second stage alarm and automatic shutdown of machinery are required ~~by *Table 1.9.1 Engines for propulsion purposes: Alarms and slow-downs* and *Table 1.9.2 Engines for propulsion purposes: Automatic shutdowns* and *Table 1.9.3 Auxiliary engines: Alarms and shutdowns*,~~ in the relevant Tables of this Section, the sensors and circuits utilised for the second stage alarm and automatic shutdown are to be independent of those required for the first stage alarm.

Existing paragraph 9.6.5 has been renumbered 7.6.5.

~~9.7~~ 7.7 Engines for propulsion purposes

~~9.7.1~~ 7.7.1 Alarms and safeguards are indicated in *Vol 2, Pt 2, Ch 1, ~~9.7~~ 7.7 Engines for propulsion purposes ~~9.7.2~~ 7.7.2* to *Vol 2, Pt 2, Ch 1, ~~9.7~~ 7.7 Engines for propulsion purposes ~~9.7.8~~ 7.7.8* and *Table ~~1.9.1~~ 1.7.1 Engines for propulsion purposes: Alarms and slow-downs* and *Table ~~1.9.2~~ 1.7.2 Engines for propulsion purposes: Automatic shutdowns*. ~~*See also Vol 2, Pt 2, Ch 1, 9.1 General 9.1.2* and *Vol 2, Pt 2, Ch 1, 9.6 Unattended machinery 9.6.5*.~~

Table ~~1.9.1~~ 1.7.1 Engines for propulsion purposes: Alarms and slow-downs

Item	Alarm	Note
Lubricating oil sump level	Low	Engines
Lubricating oil inlet pressure*	1st stage low	Engines. Slow-down
	~~Low~~	~~Slow-down~~
Lubricating oil inlet temperature*	High	Engines
Lubricating oil filters differential pressure	High	—
Oil mist concentration in crankcase or bearing temperature	High	For automatic slow-down of crosshead engines, *see Vol 2, Pt 2, Ch 1, ~~9.1~~ 7.1 General ~~9.1.2~~ 7.1.2*. For trunk piston engines, *see Table ~~1.9.2~~ 1.7.2 Engines for propulsion purposes: Automatic shutdowns*
Cylinder lubricator flow	Low	One sensor per lubricator unit on crosshead engines. Slow-down
Thrust bearing temperature*	High	Slow-down
~~Common rail servo oil pressure~~	~~Low~~	-
Piston coolant inlet pressure	Low	If a separate system. Slow-down
Piston coolant outlet temperature*	High	Per cylinder (if a separate system). Slow-down
Piston coolant outlet flow*	Low	Per cylinder (if a separate system). Slow-down
Cylinder coolant inlet pressure or flow*	Low	Slow-down (automatic on trunk piston engines)
Cylinder coolant outlet temperature*	1st stage high	Per cylinder (if a separate system) Slow-down (automatic on trunk piston)
Engine cooling water system – oil	High	~~Where engine cooling water used in heat exchangers~~ Required for crosshead engines where

content		engine cooling water used in oil/water heat exchangers
Sea-water cooling pressure	Low	—
Fuel valve coolant pressure	Low	If a separate system
Fuel valve coolant temperature	High	If a separate system
Fuel oil pressure from booster pump	Low	—
Fuel oil temperature or viscosity*	High and Low	Heavy oil only
Common rail fuel oil pressure	Low	—
Fuel oil high pressure piping*	Leakage	*See Vol 2, Pt 2, Ch 1, ~~9.6~~ 7.6 Unattended machinery 7.6.5*
Common rail servo oil pressure	Low	—
Charge air cooler outlet temperature	High ~~and Low~~	Trunk piston engines
Scavenge air temperature (fire)	High	Per cylinder, (2 stroke engines). Slow-down
Scavenge air receiver water level	High	—
Exhaust gas temperature*	High	Per cylinder. Slow-down (automatic on trunk piston engines), *see* Note 5
Exhaust gas temperature deviation from average*	High	Per cylinder, for engine power >500 kW/cylinder,~~. S~~*see* Note 5
Turbocharger speed	High	Category B and C turbochargers, *see* Notes 11 and 12
Turbocharger exhaust gas inlet temperature	High	~~Each turbocharger, *see* Note 9~~ Category B and C turbochargers, *see* Notes 6 and 12
~~Turbocharger exhaust gas outlet temperature*~~	~~High~~	~~Each turbocharger~~
Turbocharger lubricating oil inlet pressure	Low	~~*See* Note 10~~ Only for forced lubrication systems on category B and C turbochargers, *see* Notes 7, 10 and 12
Turbocharger lubricating oil outlet temperature	High	~~Each bearing, if system not integral with turbocharger. *See* Notes 8 and 10~~ Category C turbochargers, if not a forced system, oil temperature near each bearing, *see* Notes 7 and 12
Starting air pressure*	Low	Before engine manoeuvring valve
Control air pressure	Low	—
Direction of rotation	Wrong way	Reversible engines, *see also Vol 2, Pt 2, Ch 1, 7.7 Engines for propulsion purposes ~~9.7.8~~ 7.7.7*
Automatic start of engine	Failure	*See Vol 2, Pt 2, Ch 1, ~~9.7~~ 7.7 Engines for propulsion purposes ~~9.7.8~~ 7.7.7*
Electrical starting battery charge level*	Low	~~Electric start engines, *see also Vol 2, Pt 2, Ch 1, 7.2 Electrical starting arrangements 7.2.5*~~ —
Feed water or water/thermal fluid forced circulation flow (if fitted)	Low	*See Vol 2, Pt 7, Ch 3, 6.2 Feed and circulation pumps 6.2.6* and Note ~~6~~ 8
Uptake temperature	High	To monitor for soot fires. *See* Notes ~~6~~ 8 and ~~7~~ 9

Note 1. Where 'per cylinder' appears in this Table, suitable alarms may be situated on manifold outlets for trunk piston engines.

Note 2. For engines and gearing of 1500 kW or less only the items marked * are required.

Note 3. Common sensors are acceptable for alarms and slow-down functions.

Note 4. Except where stated otherwise in the Table, slow-down may be effected by either manual or automatic means, by reduction of speed or power as appropriate.

Note 5. For trunk piston engine powers <500 kW/cylinder, ~~but total power >500 kW,~~ a common sensor for exhaust gas manifold temperature may be fitted.

Note ~~9~~ 6. Alarm and indication of the exhaust gas temperature at turbocharger inlet may be waived if alarm and indication for individual exhaust gas temperature is provided for each cylinder and the alarm level is set to a value specified by the turbocharger manufacturer. For Category B turbochargers, the exhaust gas temperature may be alternatively monitored at the turbocharger outlet provided that the correlation between inlet and outlet temperatures is established and verified and the alarm level is set to a correspondingly safe level for the turbine.

Note ~~8~~ 7. Where the outlet temperature for each bearing cannot be measured due to the design, details of alternative proposals in accordance with the turbocharger manufacturer’s instructions may be submitted for consideration.

Note ~~6~~ 8. Alarm only required when an exhaust gas economiser/boiler/thermal oil heater is fitted.

Note ~~7~~ 9. Alternatively, details ~~(including location)~~ of an appropriate fire detection system are to be submitted for consideration.

Note 10. Separate sensors are to be provided if the lubrication oil system of the turbocharger is not integrated with the lubrication oil system of the engine or if it is separated by a throttle or pressure reduction valve from the engine lubrication oil system. Where the turbocharger is provided with a self-contained lubricating oil system integrated with the turbocharger, lubricating oil inlet pressure need not be monitored.

Note 11. Where multiple turbochargers are activated sequentially, speed monitoring is not required for the turbocharger(s) being activated last in the

sequence, provided that all turbochargers share the same intake air filter and they are not fitted with waste gates.
Note 12. *See Vol 2, Pt 2, Ch 1, 12.1 General 12.1.2* for details of turbocharger categorisations.

Table ~~1.9.2~~ 1.7.2 Engines for propulsion purposes: Automatic shutdowns

Item	Alarm	Note
Lubricant oil inlet pressure	2nd stage low	Automatic shutdown of engines, *see Vol 2, Pt 2, Ch 1,~~ 9.6~~ 7.6 Unattended machinery ~~9.6.4~~ 7.6.4*
Oil mist concentration in crankcase or bearing temperature	High	~~Automatic shutdown of trunk piston, s~~*See Vol 2, Pt 2, Ch 1, ~~9.1~~ 7.1 General ~~9.1.2~~ 7.1.2* for automatic shutdown of trunk piston engines; for crosshead engines *see Table 1.7.1 Engines for propulsion purposes: Alarms and slow-downs*
Cylinder coolant outlet temperature	2nd stage high	Automatic shutdown of trunk piston, *see Vol 2, Pt 2, Ch 1, ~~9.6~~ 7.6 Unattended machinery ~~9.6.4~~ 7.6.4*
Overspeed	High	Automatic shutdown of engine, *see also Vol 2, Pt 2, Ch 1, ~~9.4~~ 7.5 Overspeed protective devices*. Details of alternative proposals in accordance with the manufacturer's instructions may be submitted for consideration

~~9.7.2~~ 7.7.2 Alarms are to operate for the fault conditions shown in *Table ~~1.9.1~~ 1.7.1 Engines for propulsion purposes: Alarms and slow-downs*. Where applicable, indication is to be given at the relevant control stations that the speed or power of the main propulsion engine(s) is to be manually reduced or has been reduced automatically.

~~9.7.3~~ 7.7.3 Alarms are to operate, and automatic shutdown of machinery is to occur for the fault conditions shown in *Table ~~1.9.2~~ 1.7.2 Engines for propulsion purposes: Automatic shutdowns*.

~~9.7.4~~ 7.7.4 The following engine services are to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the propulsion engine(s):
(a) Lubricating oil supply.
(b) Piston coolant supply, where applicable.
(c) Cylinder coolant supply, where applicable.
(d) Fuel valve coolant supply, where applicable.
(e) Fuel oil supply, where fuel oil grades require heating or cooling only, *see also Vol 2, Pt 2, Ch 1, ~~9.7~~ 7.7 Engines for propulsion purposes ~~9.7.5~~ 7.7.5*.

~~9.7.5~~ 7.7.5 The ~~oil fuel~~ fuel oil supply may be fitted with an automatic control for viscosity instead of the temperature control required by *Vol 2, Pt 2, Ch 1, ~~9.7~~ 7.7 Engines for propulsion purposes ~~9.7.4~~ 7.7.4*.

~~9.7.6~~ 7.7.6 Indication of the starting air pressure is to be provided at each control station from which it is possible to start the main propulsion engine(s).

~~9.7.7~~ 7.7.7 The number of automatic consecutive attempts which fail to produce a start are to be limited to three~~ attempts~~. For reversible engines which are started and stopped for manoeuvring purposes, means are to be provided to maintain sufficient starting air in the air receivers. For electric starting, *see Vol 2, Pt 2, Ch 1, ~~7.2~~ 9.2 Electric~~al~~ starting ~~arrangements~~*.

~~9.7.8~~ 7.7.8 Prolonged running in a restricted speed range is to be prevented automatically or, alternatively, an indication of restricted speed ranges is to be provided at each control station.

~~9.8~~ 7.8 Auxiliary ~~and other~~ engines

~~9.8.1~~ 7.8.1 Alarms and safeguards are indicated in *Table ~~1.9.3~~ 1.7.3 Auxiliary engines: Alarms and shutdowns* ~~See also *Vol 2, Pt 2, Ch 1, 9.1 General 9.1.2* and *Vol 2, Pt 2, Ch 1, 9.6 Unattended machinery 9.6.5*.~~

~~9.8.2~~ 7.8.2 For engines operating on heavy fuel oil, automatic temperature o~~f~~r viscosity controls are to be provided.

Table ~~1.9.3~~ 1.7.3 Auxiliary engines: Alarms and shutdowns

Item	**Alarm**	**Note**
Lubricating oil inlet temperature	High	—
Lubricating oil inlet pressure	1st stage low	—
~~Lubricating oil inlet pressure~~	2nd stage low	Automatic shutdown of engine, *see Vol 2, Pt 2, Ch 1, ~~9.6~~ 7.6 Unattended machinery ~~9.6.4~~ 7.6.4*
Oil mist concentration in crankcase or bearing temperature	High	Automatic shutdown of engine, *see Vol 2, Pt 2, Ch 1, ~~9.1~~ 7.1 General ~~9.1.2~~ 7.1.2*

Fuel oil high pressure piping	Leakage	*See Vol 2, Pt 2, Ch 1, ~~9.6~~ 7.6 Unattended machinery ~~9.6.5~~ 7.6.5*
Coolant outlet temperature (for engines >220 kW)	1st stage high	—
~~Coolant outlet temperature (for engines >220 kW)~~	2nd stage high	Automatic shutdown of engine, *see Vol 2, Pt 2, Ch 1, ~~9.6~~ 7.6 Unattended machinery ~~9.6.5~~ 7.6.5*
Coolant pressure or flow	Low	—
Fuel oil temperature or viscosity	High and Low	Heavy oil only
Overspeed	High	Automatic shutdown of engine, *see also Vol 2, Pt 2, Ch 1, ~~9.4~~ 7.5 Overspeed protective devices*. Details of alternative proposals in accordance with the manufacturer's instructions may be submitted for consideration.
Common rail servo oil pressure	Low	—
Common rail fuel oil pressure	Low	—
Starting air pressure	Low	—
Electrical starting battery charge level	Low	~~Electric start engines, *see also Vol 2, Pt 2, Ch 1, 7.2 Electrical starting arrangements 7.2.5*~~ —
Exhaust gas temperature (for engines >500 kW/cylinder)	High	Per cylinder.
Feed water or water/thermal fluid forced circulation flow (if fitted)	Low	*See Vol 2, Pt 7, Ch 3, 6.2 Feed and circulation pumps 6.2.6* and Note ~~2~~ 3
~~Turbocharger lubricating oil outlet temperature~~	~~High~~	~~Each bearing, *see* Note 5~~
~~Turbocharger lubrication oil inlet pressure~~	~~Low~~	~~*See* Note 6~~
Uptake temperature	High	To monitor for soot fires. *See* Notes ~~2 and~~ 3 and 4
Turbocharger speed	High	Category B and C turbochargers, *see* Notes 7 and 9
Turbocharger exhaust gas inlet temperature	High	Category B and C turbochargers, *see* Notes 8 and 9
Turbocharger lubricating oil outlet temperature	High	Category C turbochargers, if not a forced system, oil temperature near each bearing, *see* Notes 6 and 9
Turbocharger lubrication oil inlet pressure	Low	Only for forced lubrication systems on category B and C turbochargers, *see* Notes 5, 6 and 9

Note ~~4~~1. For emergency engines, including engines used for the emergency source of electrical power required by SOLAS, see *Vol 2, Pt 7, Ch 3, ~~12 Air compressors and air starting arrangements~~ 12.11 Dead ship condition starting arrangements*.
Note ~~1~~2. The tailoring document or System Design Description may specify additional requirements of the Naval Administration.
Note ~~2~~3. Alarm only required when an exhaust gas economiser/boiler/thermal oil heater is fitted.
Note ~~3~~4. Alternatively, details ~~(including location)~~ of an appropriate fire detection system are to be submitted for consideration.
Note 5. ~~Unless provided with a self-contained lubricating oil system integrated with the turbocharger.~~ Separate sensors are to be provided if the lubrication oil system of the turbocharger is not integrated with the lubrication oil system of the engine or if it is separated by a throttle or pressure-reduction valve from the engine lubrication oil system.
Note 6. Where outlet temperature from each bearing cannot be monitored due to the engine/turbocharger design, alternative arrangements may be accepted. Continuous monitoring of inlet pressure and inlet temperature in combination with specific intervals for bearing inspection in accordance with the turbocharger manufacturer's instructions may be accepted as an alternative.
Note 7. Where multiple turbochargers are activated sequentially, speed monitoring is not required for the turbocharger(s) being activated last in the sequence, provided that all turbochargers share the same intake air filter and they are not fitted with waste gates.
Note 8. Alarm and indication of the exhaust gas temperature at the turbocharger inlet is not required if alarm and indication for individual exhaust gas temperature are provided for each cylinder and the alarm level is set to a value specified by the turbocharger manufacturer. For Category B turbochargers, the exhaust gas temperature may be alternatively monitored at the turbocharger outlet provided that correlation between inlet and outlet temperatures is established and verified and the alarm level is set to a correspondingly safe level for the turbine.
Note 9. *See Vol 2, Pt 2, Ch 1, 12.1 General 12.1.2* for details of turbocharger categorisations.

~~9.9~~ 7.9 ~~Alarms and safeguards for e~~Emergency engines

~~9.9.1 These requirements apply to emergency engines required to be immediately available in an emergency and capable of being controlled remotely or automatically.~~

~~9.9.2~~ 7.9.1 Alarms and safeguards are indicated in *Table ~~1.9.4~~ 1.7.4 Alarms and safeguards for emergency engines*. ~~*See also Vol 2, Pt 2, Ch 1, 9.1 General 9.1.2* and *Vol 2, Pt 2, Ch 1, 9.6 Unattended machinery 9.6.5*.~~

Table ~~1.9.4~~ 1.7.4 Alarms and safeguards for emergency engines

Item	Alarm for engine power <220kW	Alarm for engine power ≥220 kW	Note
~~Emergency Engine~~	~~≥ 220 kW~~	~~<220 kW~~	~~-~~
Fuel oil leakage from pressure pipes	Leakage	Leakage	*See Vol 2, Pt 2, Ch 1, ~~9.6~~ 7.6 Unattended machinery ~~9.6.5~~ 7.6.5*
Lubricating oil temperature	~~High~~ -	~~-~~ High	-
Lubricating oil pressure	Low	Low	-
Oil mist concentration in crankcase	~~High~~ -	~~-~~ High	*See* Note ~~1~~
Coolant pressure or flow	~~Low~~ -	~~-~~ Low	-
Coolant Temperature (can be air)	High	High	-
Overspeed	~~High~~ -	~~-~~ High	Automatic shutdown
Note ~~1.~~ For engines having a power of more than 2250 kW or a cylinder bore of more than 300 mm.			

Existing paragraphs 9.9.3 to 9.9.7 have been renumbered 7.9.2 to 7.9.6.

~~9.5~~ 7.10 Additional requirements for ~~E~~engine stopping for naval vessels

~~9.5.1~~ 7.10.1 At least two independent means of stopping the engines quickly from the control station under any conditions are to be available.

■ *Section 8*
Piping

8.1 ~~Oil fuel~~ Fuel oil, hydraulic and high-pressure oil systems

8.1.1 ~~Oil fuel~~ Fuel oil and hydraulic oil piping systems are to comply with *Vol 2, Pt 7, Ch 1 Piping Design Requirements* and ~~*Vol 2, Pt 2, Ch 3 Steam Turbines*~~ *Vol 2, Pt 7, Ch 3 Machinery Piping Systems* as applicable.

8.1.2 Engine fuel system components are to be designed to accommodate the maximum peak pressures experienced in service. Where fuel injection pumps are fitted, ~~this applies in~~ particular attention is to be given to the fuel injection pump supply and spill line piping which may be subject to high-pressure pulses from the pump. Connections on such piping systems should be chosen to minimise the risk of pressurised oil fuel leaks. Fatigue analysis may be considered necessary to establish the suitability of the piping system components for the pressures and fluctuating stresses that the pipe system may be subject to in normal service.

8.1.3 On engines used for propulsion, ~~W~~where fuel oil and hydraulic oil pressure pumps are fitted, and these ~~pumps~~ are essential for engine operation, not less than two fuel oil and two hydraulic oil pressure pumps are to be provided ~~for their respective service~~ and arranged such that failure of one pump does not render the other pump(s) inoperative. Each fuel oil pump and hydraulic oil pump is to be capable of supplying the quantity of oil for engine operation at its maximum continuous rating and arranged ready for immediate use.

8.1.4 ~~All e~~External high pressure fuel delivery piping between the fuel injection pump or high pressure fuel pumps and the fuel injectors is to be protected with a jacketed piping system capable of containing leakage and/or spray of flammable fluid from a high pressure line failure. The jacketed piping arrangements are to be approved, *see Table ~~1.2.1~~ 1.1.1 Plans and particulars to be submitted*. The protection of high-pressure fuel pipes on common rail fuel systems will be specially considered.

8.1.5 The protection required by *Vol 2, Pt 2, Ch 1, 8.1 ~~Oil fuel~~ Fuel oil, hydraulic and high-pressure oil systems 8.1.4* is to prevent fuel oil or fuel oil mist from reaching a source of ignition on the engine or its surroundings. Suitable drainage arrangements are to be made for draining any fuel oil leakage to one or more collector tank(s) fitted in a safe position ~~and for preventing contamination of lubricating oil by fuel oil~~. These tanks are to be separate from any tank used to collect other oils such as lube oil or hydraulic oil to prevent cross-contamination. An alarm is to be provided to indicate that leakage is taking place. The collector tank arrangement is to be approved.

8.1.6 The hydraulic oil pressure piping between the high pressure hydraulic pumps and hydraulic actuators is to be protected with a jacketed piping system or suitable enclosure capable of containing hydraulic oil leakage from a high pressure pipe failure. Where flammable oils are used in high-pressure systems to operate exhaust valves, the oil pipe lines between the high-pressure oil pump and actuating oil pistons are to be protected with a jacketed piping system capable of preventing oil spray from a high-pressure line failure.

8.1.7 All lubricating and hydraulic oil pipes and oil fuel pipes that are not jacketed nor suitably enclosed are to be suitably installed and screened to avoid oil spray or leakage onto hot surfaces, *see also Vol 2, Pt 7, Ch 3, 2.9 Precautions against fire 2.9.4* and *Vol 2, Pt 7, Ch 5, 11.10 Precautions against fire 11.10.2* as applicable.

8.1.8 Where flammable oils are used in high-pressure actuating systems, a fatigue analysis is to be carried out in accordance with a suitable standard and all anticipated pressure, pulsation and vibration loads are to be considered. The analysis is to demonstrate that the design and arrangements are such that the likelihood of failure is as low as reasonably practicable. The analysis is to identify all assumptions made and standards to be applied during manufacture and testing. Any potential weak points that may develop due to incorrect construction or assembly are also to be identified.

8.1.9 Accumulators and associated high pressure piping are to be designed, manufactured and tested in accordance with a standard applicable to the maximum pressure and temperature rating of the system.

~~8.1.11~~ 8.1.10 For high pressure oil containing and mechanical power transmission systems, the quality plan for sourcing, design, installation and testing of components is to address the following issues (*see Table ~~1.2.1~~ 1.1.1 Plans and particulars to be submitted*, Note 11):
(a) Design and manufacturing standard(s) applied.
(b) Materials used for construction of key components and their sources.
(c) Details of the quality control system applied during manufacture and testing.
(d) Details of type approval, type testing or approved type status assigned to the machinery or equipment.
(e) Details of installation and testing recommendations for the machinery or equipment.

8.2 Additional requirements for fuel oil, hydraulic and high pressure oil systems for naval vessels

~~8.1.10~~ 8.2.1 Where multi-engined installations are supplied from the same fuel source, means of isolating the fuel supply and spill piping to individual engines is to be provided. These means of isolation are not to affect the operation of the other engines and are to be operable from a position not rendered inaccessible by a fire on any of the engines~~, *see also Vol 2, Pt 1, Ch 3, 4.15 Stopping of machinery*~~.

~~8.1.12~~ 8.2.2 Means are to be provided safely to purge the fuel oil system of air.

~~8.1.13~~ 8.2.3 Short lengths of synthetic rubber hoses that comply with the requirements of *Vol 2, Pt 7, Ch 1, 13 Flexible hoses* may be used to accommodate relative movement between machinery and fixed piping systems.

~~8.2~~ 8.3 ~~Intake and e~~Exhaust systems

~~8.2.1~~ 8.3.1 Where the surface temperature of the exhaust pipes and silencer may exceed 220°C, they are to be water cooled or efficiently lagged to minimise the risk of fire and to prevent damage by heat. Where lagging covering the exhaust piping system including flanges is oil-absorbing or may permit penetration of oil, the lagging is to be encased in sheet metal or equivalent. In locations where the Surveyor is satisfied that oil impingement could not occur, the lagging need not be encased.

~~8.2.3~~ 8.3.2 Where the exhausts of two or more engines are led to a common silencer or exhaust gas-heated boiler or economiser, an isolating device is to be provided in each exhaust pipe.

~~8.2.4~~ 8.3.3 For alternatively fired furnaces of boilers using exhaust gases and oil fuel, the exhaust gas inlet pipe is to be provided with an isolating device and interlocking arrangements whereby oil fuel can only be supplied to the burners when the isolating device is closed to the boiler.

~~8.2.5~~ 8.3.4 In two-stroke main engines fitted with exhaust gas turbochargers which operate on the impulse system, provision is to be made to prevent broken piston rings entering the turbine casing and causing damage to blades and nozzle rings.

~~8.2.2~~ 8.3.5 Where the exhaust is led overboard near the waterline, the exhaust system shall be so designed as to prevent water from entering the engine exhaust manifold through wave or wake action, both when the engine is in operation or shutdown. The system shall also be designed to prevent ingress of water at the angles of inclination as shown in *Vol 2, Pt 1, Ch 3, 4.6 Inclination of ship*.~~means are to be provided to prevent water from being siphoned back to the engine. Where the exhaust is cooled by water spray, the exhaust pipes are to be self-draining overboard. Erosion/corrosion resistant shut-off flaps or other devices are to be fitted on the hull side shell or pipe end and acceptable arrangements made to prevent water flooding the space or entering the engine exhaust manifold.~~

8.3.6 Where the exhaust is cooled by water spray, the exhaust pipes are to be self-draining overboard. Suitable measures shall be taken to prevent inadvertent closure of drain valves where this may lead to sprayed water entering the engine. Means shall be provided to prevent water from flowing back into the engine when the engine is stopped.

8.3.7 Exhaust systems having components sensitive to heat shall be fitted with a high temperature alarm after water injection. This alarm shall be integrated into the ship’s alarm system.

8.3.8 Exhaust pipes penetrating the shell below the bulkhead deck shall be provided with a shipside valve or other approved positive means of closure at the shell to prevent back-flooding into the hull through a damaged exhaust system.

8.3.9 The exhaust system shall be designed such that the exhaust back-pressure is within the allowable limits stated by the engine manufacturer under all expected operating conditions.

8.4 Additional requirements for exhaust systems for naval vessels

~~8.2.6~~ 8.4.1 The ~~air intakes and~~ exhausts are to be in accordance with the engine manufacturer's design and installation requirements. Particular attention is drawn to the requirements on pressure and flow conditions to be achieved throughout the ~~intake and~~ exhaust systems. ~~The arrangements are to comply with *Vol 2, Pt 2, Ch 1, 8.2 Intake and exhaust systems 8.2.7* as applicable.~~

~~8.2.8~~ 8.4.2 Each engine is to have an independent exhaust system unless arrangements are made to address risks associated with combined exhausts e.g back pressure, trapped combustion products and unburned fuel vapours.

~~8.2.9~~ 8.4.3 The arrangement of the exhaust system is to be such as to prevent exhaust gases being drawn into the manned spaces, air conditioning systems and air intakes. They should not discharge into air cushion intakes.

~~8.2.10~~ 8.4.4 The design of exhaust systems is to prevent deterioration of engine parts resulting from ingress of sea or rain water via the exhaust ducting when the engine is not in use. Drainage arrangements are to be provided and are to be led to a tank suitable for the potentially corrosive nature of any drainage.

~~8.2.11~~ 8.4.5 Exhaust systems are not to pass through accommodation spaces.

~~8.2.12~~ 8.4.6 The exhaust system is to accommodate thermal expansion and movement of the duct due to the combined effects of operating the engines and flexure of the ship's structure.

~~8.2.13~~ 8.4.7 The exhaust ducting and silencers are to be designed and installed to minimise the risk of unburnt fuel collecting inside the duct.

~~8.2.14~~ 8.4.8 The design of the exhaust ducting and associated equipment is to minimise the risk of soot collecting at any point other than those specifically intended for soot removal. Inspection and access openings are to be provided.

~~8.2.15~~ 8.4.9 Plastic pipes intended for exhaust systems are to be in accordance with a recognised Code or Standard suitable for the intended service conditions.

~~8.3~~ 8.5 Starting air pipe systems and safety fittings

~~8.3.1 Air start piping systems are, in general, to comply with the requirements of *Vol 2, Pt 7, Ch 1 Piping Design Requirements*, with due regard being paid to the particular type of installation.~~

Existing paragraphs 8.3.2 to 8.3.8 have been renumbered 8.5.1 to 8.5.7.

Existing paragraph 8.4 has been renumbered 8.6

~~8.5~~ 8.7 Requirements for ~~L~~lubricating oil systems for naval vessels

~~8.5.1~~ 8.7.1 The lubrication system for each engine is to be independent from any other engine. A common lubricating oil storage tank arrangement may be provided.

~~8.5.2~~ 8.7.2 Each engine is to be provided with a means of checking the running and static level of oil in the system/engine.

~~8.5.3~~ 8.7.3 Means are to be provided to purge safely lubricating oil systems of air.

~~8.5.4~~ 8.7.4 All vent pipes are to be arranged with a continuous upward slope of at least 10° to prevent the collection of oil in pockets and bends.

~~8.5.5~~ 8.7.5 Oil sampling arrangements with the ability to take samples when the engine is running are to be fitted with valves or cocks of the self-closing type and located in positions as far removed as possible from any heated surface or electrical equipment.

~~8.6~~ 8.8 Requirements for ~~A~~air ~~induction~~ intake systems for naval vessels

8.8.1 The air intakes are to be in accordance with the engine manufacturer's design and installation requirements. Particular attention is drawn to the requirements on pressure and flow conditions to be achieved throughout the intake system.

~~8.2.7~~ 8.8.2 Engine intakes are to be arranged to provide sufficient air to the engines whilst minimising the ingestion of harmful particles.

~~8.6.1~~ 8.8.3 An air filter is to be fitted at the inlet to each engine. The air filters are to satisfy the following:

(a) Be readily removable for cleaning.

(b) Have an efficiency of not less than 98 per cent at 100 per cent of rated flow capacity when tested to an acceptable standard specified by the manufacturer.
(c) Be provided with an indicator, such as a pressure drop indicator, to indicate when a filter requires cleaning.
(d) Be of a design that does not degrade the performance of the engine.
(e) For engines drawing air from the engine compartment, be as close as possible to the engine air inlet and in such cases, the debris screen required by *Vol 2, Pt 2, Ch 1,* ~~*8.6*~~ *8.8 Requirements for* ~~*A*~~*air* ~~*induction*~~ *intake systems for naval vessels* ~~*8.6.4*~~ *8.8.6*~~.~~*(c)* may be omitted.

~~8.6.2~~ 8.8.4 Where there is a requirement to provide a ducted air system to convey air from inlets on deck to the engine, the requirements of *Vol 2, Pt 2, Ch 1,* ~~*8.6*~~ *8.8 Requirements for* ~~*A*~~*air* ~~*induction*~~ *intake systems for naval vessels* ~~*8.6.3*~~ *8.8.5* to *Vol 2, Pt 2, Ch 1,* ~~*8.6*~~ *8.8 Requirements for* ~~*A*~~*air* ~~*induction*~~ *intake systems for naval vessels* ~~*8.6.6*~~ *8.8.8* are to be complied with.

~~8.6.3~~ 8.8.5 The ducting is to be led by the most direct route practicable consistent with the arrangement of adjacent systems and equipment.

~~8.6.4~~ 8.8.6 Each ducted air supply is to have the following:
(a) Means to prevent sea spray, aerosol salt and sand reaching the engine and means to remove any such substances that enter the intakes or their bypass arrangements. Suitable drainage arrangements to remove any water from intakes and intake bypass arrangements (where fitted) to guard against the risk of icing are also to be provided.
(b) Means of ensuring that loads are not transmitted from the engine to the ducting, such as a flexible bellows, *see Vol 2, Pt 7, Ch 1, 14 Expansion pieces.*
(c) A debris screen that is easily accessible for cleaning located close to the engine.

~~8.6.5~~ 8.8.7 The design of induction air systems is to provide a nominal constant air speed that should be as low as reasonably practicable to minimise pressure losses. The inlet pressure drop across the system, including filters and silencers, etc. is not to exceed the engine manufacturer's recommendations.

~~8.6.6~~ 8.8.8 Air induction system intakes are to be designed and installed such that turbulent flow is not induced therein by ship motions.

■ *Section* ~~*7*~~ *9*
Starting arrangements

~~7.1~~ 9.1 Air starting

~~7.1.1~~ 9.1.1 Air starting arrangements are to meet the requirements of *Vol 2, Pt 7, Ch 3, 12 Air compressors and air starting arrangements*.

~~7.2~~ 9.2 Electrica~~l~~ starting~~ arrangements~~

Existing paragraphs 7.2.1 to 7.2.5 have been renumbered 9.2.1 to 9.2.5.

~~7.2.7 The requirements for battery installations are given in *Vol 2, Pt 9 Electrotechnical Systems*.~~

9.3 Additional requirements for electric starting for naval ships

~~7.2.6~~ 9.3.1 Transient electrical loads due to starting of engines are not to interfere with power supplies to control and weapons systems.

~~7.3~~ 9.4 Starting of the emergency source of power

~~7.3.1~~ 9.4.1 Emergency generators are to be capable of being readily started in their cold conditions down to a temperature of 0ºC. If this is impracticable, or if lower temperatures are likely to be encountered, consideration is to be given to the provision and maintenance of heating arrangements, so that ready starting will be assured.

Existing paragraphs 7.3.2 to 7.3.3 have been renumbered 9.4.2 to 9.4.3.

~~7.3.4~~ 9.4.4 Electronically controlled emergency engines are to comply with the additional requirements of *Vol 2, Pt 2, Ch 1,* ~~*13.5*~~ *4.5 Additional requirements for* ~~*E*~~*emergency engines for naval vessels*.

Existing paragraphs 7.3.5 to 7.3.6 have been renumbered 9.4.5 to 9.4.6.

~~7.3.7~~ 9.4.7 Electric starting arrangements are to also satisfy *Vol 2, Pt 2, Ch 1,* ~~*7.2*~~ *9.2 Electrical starting* ~~*arrangements 7.2.2*~~ *9.2.2* to *Vol 2, Pt 2, Ch 1, 9.2 Electrical starting 9.2.5* and *Vol 2, Pt 2, Ch 1, 9.3 Additional requirements for electric starting for naval ships 9.3.1*.

~~7.4~~ 9.5 Engine control, alarm, monitoring and safety system power supplies

Existing paragraph 7.4.1 has been renumbered 9.5.1.

~~7.4.2~~ 9.5.2 Where adequate battery and charging capacity exists, an engine-starting battery may be used as one source of electrical power required by ~~*Vol 2, Pt 2, Ch 1, 8.2 Intake and exhaust systems 8.2.6*~~ *Vol 2, Pt 2, Ch 1, 9.5 Engine control, alarm, monitoring and safety system power supplies 9.5.1*.

Existing paragraph 7.4.3 has been renumbered 9.5.3.

■ *Section ~~6~~ 10*
Safety arrangements ~~on engines~~

~~6.1~~ 10.1 Relief valves

~~6.1.1~~ 10.1.1 Scavenge spaces in open connection with cylinders are to be provided with explosion relief valves. ~~The valves are to be arranged and positioned on engines to minimise the possibility of danger and damage arising from emission from the valves.~~

~~6.1.2~~ 10.1.2 Crankcases are to be provided with lightweight spring-loaded valves or other quick-acting and self-closing devices, to relieve the crankcases of pressure in the event of an internal explosion and to prevent any inrush of air thereafter. The valves are to be designed and constructed to open quickly and be fully open at a pressure not greater than 0,2 bar. ~~Crankcase relief valves are to be type tested in accordance with *Vol 2, Pt 2, Ch 1, 12 Type Testing – General*.~~

Existing paragraph 6.1.3 has been renumbered 10.1.3.

~~6.1.4~~ 10.1.4 Each valve is to be fitted with a flame arrester that permits flow for crankcase pressure relief and prevents the passage of flame following a crankcase explosion. The valves are to be type tested in a configuration that represents the installation arrangements that will be used on an engine and in accordance with ~~*Vol 2, Pt 2, Ch 1, 12 Type Testing – General*~~ *Vol 2, Pt 2, Ch 1, 13.3 Crankcase explosion relief valves*. The valves are to be positioned on engines to minimise the possibility of danger and damage arising from emission of the crankcase atmosphere. Where shielding from the emissions is fitted to a valve, the valve is to be tested to demonstrate that the shielding does not adversely affect the operational effectiveness of the valve.

~~6.1.5~~ 10.1.5 The valves are to be provided with a copy of the manufacturer's installation and maintenance manual that is pertinent to the size and type of valve being supplied for installation on a particular engine. The manual is to contain the following information:
~~(a)~~ ● Description of valve with details of function and design limits.
~~(b)~~ ● Copy of type test certification.
~~(c)~~ ● Installation instructions.
~~(d)~~ ● Maintenance in service instructions to include testing and renewal of any sealing arrangements.
~~(e)~~ ● Actions required after a crankcase explosion.

Existing paragraph 6.1.6 has been renumbered 10.1.6.

~~6.1.7~~ 10.1.7 Plans showing details and arrangements of the relief valves are to be submitted for approval. ~~*s*~~*See* ~~*Vol 2, Pt 2, Ch 1, 2.1 Approval process*~~ *Vol 2, Pt 2, Ch 1, 1.4 Submission requirements.*

~~6.1.8~~ 10.1.8 The valves are to be provided with suitable markings that include the following information:
~~(a)~~ ● Name and address of manufacturer.
~~(b)~~ ● Designation and size.
~~(c)~~ ● Month/Year of manufacture.
~~(d)~~ ● Approved installation orientation.

Existing sub-Section 6.2 has been renumbered 10.2.

~~6.3~~ 10.3 Size of relief valves

Existing paragraphs 6.3.1 to 6.3.3 have been renumbered 10.3.1 to 10.3.3.

~~6.3.4~~ 10.3.4 In determining the volume of the crankcase for the purpose of calculating the combined free area of the crankcase relief valves, the volume of the stationary parts within the crankcase may be deducted from the total internal volume of the crankcase. ~~The volume of the rotating and reciprocating components are to be included.~~

~~6.4~~ 10.4 Vent pipes

~~6.4.1~~ 10.4.1 Through ventilation~~ of crankcase~~, and any arrangement which could produce a flow of external air within the crankcase, is in principle not permitted except for trunk piston type dual fuel engines where crankcase ventilation is to be provided.

Where crankcase vent or breather pipes are fitted, they are to be made as small as practicable and/or as long as possible to minimise the inrush of air after an explosion. Vents from crankcases of main engines are to be led to a safe position on deck or other approved position.

Existing paragraphs 6.4.2 to 6.4.3 have been renumbered 10.4.2 to 10.4.3.

Existing sub-Section 6.5 has been renumbered 10.5.

~~6.6~~ 10.6 Crankcase access and lighting

Existing paragraph 6.6.1 has been renumbered 10.6.1.

~~6.6.2~~ 10.6.2 When interior lighting is provided it is to be flameproof ~~(Ex ‘d’)~~ in relation to the interior and details of which are to be submitted for approval~~, *see also Vol 2, Pt 9, Ch 3, 9 Equipment – heating, lighting and accessories*~~. No wiring is to be fitted inside the crankcase.

Existing sub-Section 6.7 has been renumbered 10.7.

~~6.8~~ 10.8 Oil mist detection

10.8.1 Oil mist detection or engine bearing temperature monitors are to be provided:

(a) When arrangements are fitted to override the automatic shutdown for excessive reduction of the lubricating oil supply pressure;
(b) For engines of 2250 kW and above or having cylinders of more than 300 mm bore.

~~6.8.1~~ 10.8.2 Where crankcase oil mist detection/monitoring arrangements are fitted, they are to be of a ~~type approved~~ Type Approved by LR, tested in accordance with *Vol 2, Pt 2, Ch 1, ~~12 Type Testing – General~~ 13.4 Crankcase oil mist detection system* and comply with *Vol 2, Pt 2, Ch 1, ~~6.8~~ 10.8 Oil mist detection ~~6.8.8~~ 10.8.9* to *Vol 2, Pt 2, Ch 1, ~~6.8~~ 10.8 Oil mist detection ~~6.8.15~~ 10.8.16*.

(Part only shown)
~~6.8.2~~ 10.8.3 The oil mist detection system and arrangements are to be installed in accordance with the engine designer's and oil mist manufacturer's instructions/recommendations. The following particulars are to be included in the instructions:

(a) A ~~S~~schematic layout of the engine oil mist detection and alarm system showing locations of engine crankcase sample points and cabling/piping arrangements together with pipe dimensions to the detector.

Existing paragraphs 6.8.3 to 6.8.7 have been renumbered 10.8.4 to 10.8.8.

~~6.8.8~~ 10.8.9 The oil mist detection arrangements are to provide an alarm indication in the event of a foreseeable functional failure in the equipment and installation arrangements. *See ~~Vol 2, Pt 9, Ch 1, 2.4 Earthing and bonding 2.4.5~~ Vol 2, Pt 9, Ch 7, 4.5 Control systems, general requirements 4.5.4*.

Existing paragraphs 6.8.9 to 6.8.10 have been renumbered 10.8.10 to 10.8.11.

~~6.8.11~~ 10.8.12 Schematic layouts showing details and arrangements of oil mist detection and alarm systems are to be submitted. *See ~~Vol 2, Pt 2, Ch 1, 2.1 Approval process~~ Vol 2, Pt 2, Ch 1, 1.4 Submission requirements*.

Existing paragraphs 6.8.12 to 6.8.13 have been renumbered 10.8.13 to 10.8.14.

~~6.8.14~~ 10.8.15 Where ~~engine bearing temperature monitors or~~ alternative methods are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase, detailed information is to be submitted for consideration. The information is to include:

(a) Engine particulars - type, power, speed, stroke, bore and crankcase volume.
(b) Details of arrangements designed to prevent the ~~build up~~ build-up of potentially explosive conditions within the crankcase, e.g. bearing temperature monitoring, oil splash temperature monitoring, crankcase pressure monitoring~~,~~ and recirculation arrangements.
(c) Evidence to demonstrate that the arrangements are effective in preventing the ~~build up~~ build-up of potentially explosive conditions together with details of in-service experience.
(d) Operating instructions and the maintenance and test instructions.

Existing paragraph 6.8.15 has been renumbered 10.8.16.

~~6.9~~ 10.9 Requirements for ~~E~~emergency operation for naval vessels

~~6.9.1~~ 10.9.1 Engines and their service systems are to be capable of operation for a period of not less than eight hours when the engine compartment is flooded by sea-water to a mean level corresponding to the height of the lowest part of the engines' crankshaft main bearing journals with the ship in the most limiting trim.

■ *Section ~~10~~ 11*
Factory Acceptance Test and Shipboard Trials of Internal Combustion Engines

Existing sub-Section 10.1 has been renumbered 11.1.

~~10.2~~ 11.2 General

~~10.2.1~~ 11.2.1 Engines which are to be subjected to trials on the test bed at the manufacturer’s works and under attendance by the Surveyor(s) are to be tested in accordance with the scope of works trials specified in *Vol 2, Pt 2, Ch 1, ~~10.3~~ 11.3 Works trials (factory acceptance test)*. The scope of the trials is to be agreed between the LR Surveyor and the manufacturer prior to testing. ~~At the discretion of the Surveyor, the scope of the trials may be extended depending on the engine application.~~

Existing paragraphs 10.2.2 to 10.2.5 have been renumbered 11.2.2 to 11.2.5.

~~10.2.6~~ 11.2.6 Where the type test was not carried out on the complete engine, as described in *Vol 2, Pt 2, Ch 1, ~~1.1 Application 1.1.5~~ 1.2 Scope 1.2.2*, integration tests are to be conducted as part of the works or shipboard trials to confirm satisfactory operation of the complete engine. This includes satisfactory functioning on all fuel types on which the engine is to operate. *See also Vol 2, Pt 2, Ch 1, ~~10.4~~ 11.4 Shipboard trials ~~10.4.7~~ 11.4.6*.

~~10.3~~ 11.3 Works trials (factory acceptance test)

~~10.3.1~~ 11.3.1 The purpose of the works trials is to verify design parameters such as power, adherence to approved limits (e.g. maximum pressure) and functionality, and to establish reference values or base lines for later reference in the operational phase.

11.3.2 During testing the environmental conditions are to be recorded, including ambient air temperature, ambient air pressure and atmospheric humidity.

~~10.3.2~~ 11.3.3 For each load point the parameters to be recorded include: ~~P~~power and speed; ~~F~~fuel index (or equivalent reading); ~~M~~maximum combustion pressures; ~~E~~exhaust gas temperature before turbine and from each cylinder (or from manifold, *see* Note 5 in ~~Table 1.9.1 Engines for propulsion purposes: Alarms and slow-downs~~ *Table 1.7.1 Engines for propulsion purposes: Alarms and slow-downs*); ~~C~~charge air temperature and pressure; and turbocharger speed (only for category B and C turbochargers).

Existing paragraphs 10.3.3 has been renumbered 11.3.4.

~~10.3.4~~ 11.3.5 In each case given in *Table ~~1.10.1~~ 1.11.1 Scope of works trials for engines* ~~Scope of works trials for engines~~, all measurements conducted at the various load points are to be carried out at steady operating conditions. The readings for MCR, i.e. 100 per cent power (rated maximum continuous power at corresponding rpm) are to be taken twice at an interval of at least 30 minutes. For all load points provision should be made for time needed by the Surveyor to carry out visual inspections.

~~10.3.5~~ 11.3.6 Calibration records for the instrumentation are, upon request, to be presented to the attending Surveyor ~~upon request~~.

Table ~~1.10.1~~ 1.11.1 Scope of works trials for engines

Main engines driving propellers and waterjets		
Trial condition	Duration	Note
100% power (rated power) at rated engine speed, R	≥60 minutes	~~After having reached steady conditions~~ —
110% power at engine speed corresponding to 1,032*R	~~30–45 minutes~~ 15 minutes	Or ~~A~~after having reached steady conditions, whichever is shorter, ~~(~~*see* Notes 1~~)~~ and 4
Approved intermittent overload (if applicable)	—	Testing for duration to be agreed with the manufacturer
90% (or maximum continuous power), 75%, 50% and 25%	—	Powers in accordance with the nominal propeller curve, sequence to be selected by the manufacturer
~~Starting and r~~Reversing manoeuvres (if applicable)	—	—
Testing of governor and independent overspeed protective device	—	*See Vol 2, Pt 2, Ch 1, ~~7.2 Electrical starting arrangements~~ 7 Control and monitoring of main, auxiliary and emergency engines*
Shutdown device	—	*See Vol 2, Pt 2, Ch 1, ~~7.4 Engine control, alarm, monitoring and safety system power supplies~~ 7 Control and monitoring of main, auxiliary and emergency engines*
Engines driving generators for electric propulsion or driving generators for auxiliary purposes		

Trial condition	Duration	Note
100% power (rated power) at rated engine speed, R	≥~~50~~60 minutes	~~After having reached steady conditions (*see* Note 2)~~ —
110% power	~~30~~15 minutes	Or ~~A~~after having reached steady conditions, ~~(*see* Notes 2 and 3)~~ *see* Note 2. For auxiliary engines, *see* Note 1
75%, 50% and 25% power and idle run	—	~~(*s*~~*See* Note 2~~)~~
Start-up tests	—	—
Testing of governor and independent overspeed protective device	—	*See Vol 2, Pt 2, Ch 1,~~ 7.3 Starting of the emergency source of power~~ 7 Control and monitoring of main, auxiliary and emergency engines*
Shutdown device	—	*See Vol 2, Pt 2, Ch 1,~~ 7.4 Engine control, alarm, monitoring and safety system power supplies~~ 7 Control and monitoring of main, auxiliary and emergency engines*
Propulsion engines driving power take off (PTO) generator		
Trial condition	Duration	Note
100%power (rated power) at rated engine speed, *R*	≥60 minutes	—
110% power	15 minutes	Or after having reached steady conditions, *see* Note 3
Approved intermittent overload (if applicable)	—	Testing for duration to be agreed with the manufacturer
90% (or normal continuous cruise power), 75%, 50% and 25%	—	For variable speed engines. Powers in accordance with the nominal propeller curve or at constant speed *R*, sequence to be selected by the manufacturer
Engines driving mechanical auxiliaries		
Trial condition	Duration	Note
100% power (rated power) at rated engine speed, *R*	≥30 minutes	—
110% power	15 minutes	Or after having reached steady conditions, *see* Note 1
Approved intermittent overload (if applicable)	—	Testing for duration to be agreed with the manufacturer
75%, 50% and 25%	—	For variable speed engines. Powers in accordance with the nominal propeller curve, sequence to be selected by the manufacturer
Note 1. After running on the test bed, the fuel delivery system of main engines is normally to be so adjusted that overload power cannot be given in service unless intermittent overload power is approved by LR, in which case the limit is to be adjusted to that power. The setting of the restriction is to be made as applicable to the intended fuel. Any restriction settings, and other changes to the engine's fuel injection equipment required for operation on special fuels, are to be recorded and included by the engine manufacturer. Note 2. ~~The test is to be performed at rated speed with a constant governor setting.~~ After running on the test bed, the fuel delivery system of diesel engines driving generators is to be adjusted so that full power plus a 10 per cent margin for transient regulation can be given in service after installation on board. The transient overload capability is required so that the required transient governing characteristics are achieved also at 100% loading of the engine, and so that the protection system utilised in the electric distribution system can be activated before the engine stalls. Note 3. After running on the test bed, the fuel delivery system of propulsion engines ~~driving~~ also driving power take off (PTO) generators ~~must~~ is to be adjusted ~~such that overload (110%) power can be given in service after installation on board, so that the governing characteristics including the activation of generator protective devices can be fulfilled at all times.~~ so that full power plus a margin for transient regulation can be given in service after installation on board. The transient overload capability is required so that the electrical protection of downstream system components is activated before the engine stalls. This margin may be 10% of the engine power but at least 10% of the PTO power. Note 4. Only required once for each different engine/turbocharger configuration.		

Existing paragraph 10.3.6 has been renumbered 11.3.7.

11.3.8 Turbocharger surge margin for propulsion engines is to be demonstrated as required by *Vol 2, Pt 2, Ch 1, 12.4 Matching with engine 12.4.2.*

~~10.3.7~~ 11.3.9 For electronically controlled engines:

(a) integration tests in accordance with *Vol 2, Pt 2, Ch 1, ~~2.2~~ 1.4 Submission requirements ~~2.2.3~~ 1.4.2*; and

(b) verification of engine configuration, *see Vol 2, Pt 2, Ch 1, ~~13.3~~ 4.3 Control engineering systems ~~13.3.2~~ 4.3.2*, and that the approved software quality plans, including the software configuration management process, are to be applied.

Existing paragraph 10.3.8 has been renumbered 11.3.10.

~~10.3.9 The Surveyor may require that after the trials the fuel delivery system is restricted so as to limit the engines to run at not more than 100 per cent power. The setting of the restriction is to be made as applicable to the intended fuel. Any restriction settings, and~~

~~other changes to the engine's fuel injection equipment required for operation on special fuels, are to be recorded and included by the engine manufacturer.~~

~~10.3.10 For the duration of the acceptance test, no interventions or adjustments will be made to the machinery under test.~~

Existing paragraph 10.3.11 has been renumbered 11.3.11.

~~10.4~~ 11.4 Shipboard trials

Existing paragraph 10.4.1 has been renumbered 11.4.1.

~~10.4.2~~ 11.4.2 After installation on board, engines are to undergo shipboard trials as specified in *Table ~~1.10.2~~ 1.11.2 Scope of shipboard trials* for engines. The scope of the trials may be expanded depending on the engine application, service experience or other relevant reasons, and is to be agreed between the LR Surveyor and the Shipyard prior to testing.

(Part only shown)

Table ~~1.10.2~~ 1.11.2 Scope of shipboard trials for engines

Main engines driving fixed-pitch propeller~~s~~ or waterjet (*see* Note~~s~~ 1~~ and 2~~)		
Trial condition	Duration	Note
At rated engine speed, R	≥ 4 hours	–
At engine speed corresponding to normal continuous power	≥ 2 hours	–
At engine speed corresponding to 1,032*R	30 minutes	Where the engine adjustment permits, *see Vol 2, Pt 2, Ch 1, ~~11.1 General 11.1.7~~ 11.2 General 11.2.6*
Approved intermittent overload (if applicable)	-	Testing for duration as agreed with the manufacturer
~~At minimum on-load speed~~ Minimum engine speed to be determined	–	–
Starting and reversing manoeuvres	–	*See Vol 2, Pt 2, Ch 1, 7 Starting arrangements and Vol 2* ~~and~~ *~~Pt 7, Ch 3, 12 Air compressors and air starting arrangements~~* (*see* Note 5)
~~In r~~Reverse direction of propeller rotation is to be demonstrated (during the dock or sea trials) ~~at a minimum engine speed of 0,7*R~~	10 minutes	~~–~~*See also Vol 2, Pt 2, Ch 1, 11.4 Shipboard trials 11.4.7* and *Vol 2, Pt 2, Ch 1, 11.4 Shipboard trials 11.4.8* (*see* Note 6)
Control, monitoring, alarms and safety systems	–	Operation to be demonstrated
Where imposed, test to ensure engine can pass safely through barred speed range	–	–
Main engines driving controllable pitch propellers		
Trial condition	Duration	Note
At 100% power	≥ 4 hours	*See* Note 2
Approved intermittent overload (if applicable)	–	Testing for duration as agreed with the manufacturer
With reverse pitch suitable for manoeuvring	–	*See Vol 2, Pt 2, Ch 1, 11.4 Shipboard trials 11.4.7* and *Vol 2, Pt 2, Ch 1, 11.4 Shipboard trials 11.4.8* for additional requirements in the case of a barred speed range
Control, monitoring, alarm and safety systems	–	Operation to be demonstrated
~~Single e~~Engine(s) driving ~~a~~ generator(s) for electrical propulsion ~~only~~ and/or main power supply		
Trial condition	Duration	Note
100% power (rated ~~propulsion~~ electrical power of generator)~~, see Vol 2, Pt 2, Ch 1, 10.4 Shipboard trials 10.4.3~~	≥ ~~4 hours~~ 60 minutes	~~(s~~*See* Notes 3 and 4~~)~~
At normal continuous propulsion power	≥ 2 hours	~~(s~~*See* Note~~s 3 and 4)~~
110% power (rated ~~propulsion~~ electrical power of generator)	~~30~~≥10 minutes	~~–~~*See* Note 4
~~In reverse direction of propeller rotation at a minimum speed of 70% of the nominal propeller speed~~	~~10 minutes~~	~~(*see* Notes 3 and 4)~~
Starting manoeuvres	–	~~–~~*See* Note 5
Control, monitoring, alarm and safety systems	–	Operation to be demonstrated
Demonstration of the generator prime movers' and governors' ability to handle load steps	–	*See Vol 2, Pt 2, Ch 1, 7.3 Auxiliary engine governors*

Propulsion engines driving power take off (PTO) generator		
Trial condition	Duration	Note
100 % engine power (MCR) at corresponding speed, *R*	≥ 4 hours	–
100 % propeller branch power at engine speed, *R* (unless already covered above)	2 hours	–
100 % PTO branch power at engine speed, *R*	≥ 1 hour	–
Control, monitoring, alarm and safety systems	-	Operation to be demonstrated
Engines driving mechanical auxiliaries		
Trial condition	Duration	Note
100 % engine power (MCR) at corresponding speed, *R*	≥ 30 minutes	–
Approved intermittent overload (if applicable)	–	Testing for duration as approved
Control, monitoring, alarm and safety systems	–	Operation to be demonstrated
Note 1. For main propulsion engines driving ~~controllable pitch propellers~~ reversing gears~~, waterjets or reversing gears,~~ the tests for main engines driving fixed-~~-~~pitch propellers apply as appropriate. Note 2. Controllable pitch propellers are to be tested with various propeller pitches. The 100% power test is to be conducted at rated engine speed R with a propeller pitch set of MCR (or to the maximum achievable power if 100% cannot be reached). Note 3. The tests are to be performed at rated speed with a constant governor setting. Note 4. Tests are to be based on the rated electrical powers of the electric propulsion motors. Note 5. Starting manoeuvres are to be carried out in order to verify the capacity of the starting media. The ability of reversible engines to be operated in reverse direction is to be demonstrated. *See Vol 2, Pt 1, Ch 3, 4.8 Astern power.* Note 6. Where R, or the nominal ahead propeller speed is taken at the normal ship service speed (or cruising speed). Acceptance of alternative trial conditions will be subject to consideration by LR.		

11.4.3 Engines driving electrical generators are to be tested either:

(a) at 100 per cent electrical power for at least 60 minutes and 110 per cent of rated electrical power of the generator for at least 10 minutes; or

(b) During the electrical propulsion plant test which requires testing with 100 per cent propulsion power (i.e. total electric motor capacity for propulsion) by distributing the power on as few generators as possible. The duration of this test is to be sufficient to reach stable operating temperatures of all rotating machines or for at least 4 hours.

Existing paragraph 10.4.4 has been renumbered 11.4.4.

~~10.4.5~~ 11.4.5 For electronically controlled engines:

(a) shipboard tests in accordance with *Vol 2, Pt 2, Ch 1, ~~2.2~~ 1.4 Submission requirements 1.4.3*; and

(b) verification of engine configuration, *see Vol 2, Pt 2, Ch 1, ~~13.3~~ 4.3 Control engineering systems ~~13.3~~ 4.3.2* and *Vol 2, Pt 2, Ch 1, 1.4 Submission requirements 1.4.3 (a),* and that the approved software quality plans, including the software configuration management process, are to be applied.

~~10.4.6~~ 11.4.6 The suitability of an engine to burn residual or other special fuels is to be demonstrated where the machinery installation is arranged to burn such fuels in service. Dual- or multi-fuel engines are to be tested on all fuels that the engine is specified to use. Where engines operate on a mix of different fuels, then this is to be demonstrated. *See also Vol 2, Pt 9, Ch 11, 1.7 Unattended machinery space operation - UMS notation*.

Existing paragraphs 10.4.7 and 10.4.8 have been renumbered 11.4.7 and 11.4.8.

11.4.9 In addition to the tests listed in *Table 1.11.2 Scope of ship board trials for engines*, other tests may also be required by statutory regulations (e.g. the testing of exhaust gas emissions is to comply with *MARPOL - International Convention for the Prevention of Pollution from Ships* as applicable).

■ *Section ~~11~~ 12*
Turbochargers

~~11.1~~ 12.1 General

~~11.1.1~~ 12.1.1 Turbochargers are to be approved, either separately or as a part of an engine. ~~The requirements are written for exhaust gas driven turbochargers, but apply in principle also for engine driven chargers.~~

~~11.1.2~~ 12.1.2 ~~Some requirements are reduced for turbochargers manufactured on the basis of mass production methods. Mass produced turbochargers are defined as those which are produced under the following criteria:~~

~~(a) In quantity under strict quality control of material and parts, according to a quality assurance scheme acceptable to LR.~~

~~(b) By the use of jigs and automatic machine tools designed to machine parts to specified tolerances for interchangeability, and which are verified on a regular inspection basis.~~
~~(c) By assembly with parts taken from stock and requiring little or no fitting.~~
~~(d) With bench tests carried out on individual assembled turbochargers according to a specified programme.~~
~~(e) With appraisal by final examination of turbochargers selected at random after workshop testing.~~

The requirements escalate with the size of the turbochargers. The parameter for size is the engine power (at MCR) supplied by a group of cylinders served by the actual turbocharger, e.g. for a V-engine with one turbocharger for each bank, the size is half of the total engine power. Turbochargers are categorised in three groups depending on served power by cylinder groups with:
(a) Category A: ≤ 1000 kW;
(b) Category B: > 1000 kW and ≤ 2500 kW;
(c) Category C: > 2500 kW.

~~11.1.3~~ 12.1.3 Plans and particulars are to be submitted as required by *Vol 2, Pt 2, Ch 1,* ~~*2.2*~~ *1.4 Submission requirements* ~~*2.2.4*~~ *1.4.5*.

~~11.1.4~~ 12.1.4 Alarms and slowdowns for turbochargers are required as listed in *Table* ~~*1.9.1*~~ *1.7.1 Engines for propulsion purposes: Alarms and slow-downs*~~*, Table 1.9.2 Engines for propulsion purposes: Automatic shutdowns*~~ and *Table* ~~*1.9.3*~~ *1.7.3 Auxiliary engines: Alarms and shutdowns*.

Existing paragraph 11.1.5 has been renumbered 12.1.5.

~~11.1.6~~ 12.1.6 Category B and C turbochargers (new turbocharger types or developments of existing types) are to be Type Approved. A ~~T~~type test, see *Vol 2, Pt 2, Ch 1, 1~~2~~3.2 Turbochargers*, is to be carried out on a standard unit taken from the assembly line and is to be witnessed by the Surveyor.

~~11.1.7 LR reserves the right to limit the duration of validity of approval of a mass produced turbocharger. LR is to be informed, without delay, of any change in the design of the turbocharger, in the manufacturing or control processes, in the selection of materials or in the list of subcontractors for main parts.~~

12.1.7 The air inlet of turbochargers is to be fitted with a filter.

~~11.2 Dynamic balancing~~

~~11.2.1 All rotors are to be dynamically balanced on final assembly to the Surveyor's satisfaction.~~

~~11.3 Overspeed tests~~

~~11.3.1 All fully bladed rotor sections and impeller/inducer wheels are to be overspeed tested for three minutes at either 20 per cent above the maximum permissible speed at room temperature or 10 per cent above the maximum permissible speed at the normal working temperature. The overspeed test may be waived for forged wheels that are individually controlled by an approved non-destructive method; this test will not be waived for wheels of the unit to be type tested.~~

~~11.4 Mechanical running tests~~

~~11.4.1 Turbochargers are to be given a mechanical running test of 20 minutes duration at the maximum permissible speed.~~

~~11.4.2 Upon application, with details of a historical audit covering previous testing of turbochargers manufactured under an approved quality assurance scheme, consideration will be given to confining the test outlined in *Vol 2, Pt 2, Ch 1, 11.3 Overspeed tests 11.3.1* to a representative sample of turbochargers.~~

~~11.5 Containment~~

~~11.5.1 In the event of any rotor burst, the turbocharger casing is to fully contain all debris and no part may penetrate the casing of the turbocharger or escape through the air intake.~~

~~11.5.2 Containment is to be demonstrated by testing which is to be fully documented. For approval of a generic range of turbochargers, subject to satisfactory performance, only the largest unit is required to be tested. In any case, it must be demonstrated (e.g. by calculation) that the selected test unit is representative for the whole generic range.~~

~~11.5.3 The minimum test speeds for rotor burst testing is to be the same as those required for the overspeed test specified in *Vol 2, Pt 2, Ch 1, 11.3 Overspeed tests 11.3.1*.~~

~~11.5.4 Containment tests are to be performed at working temperature.~~

~~11.5.5 Calculations using a simulation model and numerical analysis to demonstrate the required containment may be accepted in lieu of the practical containment test, provided that:~~
~~(a) The numerical simulation model has been validated and its suitability/accuracy has been proven by direct comparison between calculation results and the practical containment test for a reference application (reference containment test). This test is to be performed at least once by the manufacturer for acceptance of the numerical simulation method in lieu of tests.~~

~~(b) The corresponding numerical simulation for the containment is performed for the same speeds as specified for the containment test.~~

~~(c) Material properties for high-speed deformations are to be applied in the numeric simulation. The correlation between normal properties and the properties at the pertinent deformation speed are to be substantiated.~~

~~(d) The design of the turbocharger regarding geometry and kinematics is similar to the turbocharger that was used for the reference containment test. In general, totally new designs will call for a new reference containment test.~~

~~11.6 Disk-shaft shrinkage fit~~

~~11.6.1 For turbochargers where the disc is connected to the shaft with an interference fit, calculations are to substantiate safe torque transmission during all relevant operating conditions such as maximum speed, maximum torque and maximum temperature gradient combined with minimum shrinkage amount.~~

~~11.7~~ 12.2 Works testing and inspection

~~11.7.1~~ 12.2.1 LR Surveyors are to be provided with free access to the manufacturer's workshop to inspect at random the quality control measures and to witness the tests required by *Vol 2, Pt 2, Ch 1, ~~11.7~~ 12.2 Works testing and inspection ~~11.7.3~~ 12.2.2* ~~to *Vol 2, Pt 2, Ch 1, 11.7 Works testing and inspection 11.7.7*~~ as deemed necessary, and to have free access to all control records and subcontractors' certificates.

~~11.7.2~~ 12.2.2 Each individual unit is to be tested in accordance with, *Vol 2, Pt 2, Ch 1, ~~11.7~~ 12.2 Works testing and inspection ~~11.7.4~~ 12.2.3* to *Vol 2, Pt 2, Ch 1, ~~11.7~~ 12.2 Works testing and inspection ~~11.7.7~~ 12.2.8*. For category C turbochargers these tests are to be conducted under survey unless an alternative approach for product assurance has been approved by LR. For category B turbochargers the testing is to be documented by a manufacturer's certificate. For category A turbochargers, test results, documented by a manufacturer's certificate, are only required if specifically requested by LR.

Existing paragraph 11.7.3 has been renumbered 12.2.3.

~~11.7.4~~ 12.2.4 Material tests (chemical composition and mechanical properties) and dimensional inspection, of the rotating parts and casing are to ~~be in accordance with the requirements of the Rules for Materials as applicable~~ confirm compliance with the approved design and material specifications (*see Vol 2, Pt 2, Ch 1, 1.4 Submission requirements 1.4.5*). Testing and inspection of turbocharger casings and rotor shafts are to comply with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials, July 2017, incorporating Notice No. 1&2* as applicable.

~~11.7.5~~ 12.2.5 ~~Pressure tests are to be carried out in accordance with *Table 1.3.1 Test and certification requirements for engine components*. Special consideration will be given where design or testing features may require modification of the test requirements.~~ Cooling spaces are to be hydraulically tested to 0,4 MPa gauge or 1,5 times maximum working pressure, whichever is higher.

12.2.6 Rotating parts are to be subjected to ultrasonic testing and surface crack detection (magnetic particle testing is to be carried out on ferromagnetic materials, penetrant testing is only to be carried out on non-ferritic materials). Ultrasonic testing is not required for components manufactured from cast iron.

~~11.7.6~~ 12.2.7 ~~Dynamic balancing and overspeed tests are to be carried out, *see Vol 2, Pt 2, Ch 1, 11.2 Dynamic balancing* and *Vol 2, Pt 2, Ch 1, 11.3 Overspeed tests*.~~ All rotors are to be dynamically balanced on final assembly.

~~11.7.7~~ 12.2.8 ~~A mechanical running, is to be carried out, *see Vol 2, Pt 2, Ch 1, 11.4 Mechanical running tests*. The duration of the running test may be reduced to 10 minutes provided that the manufacturer is able to verify the distribution of defects established during the running tests on the basis of a sufficient number of tested turbochargers. For manufacturers who have facilities in their Works for testing the turbochargers on an engine for which the turbochargers are intended, the bench test may be replaced by a test run of 20 minutes at overload (110% of the rated output) on this engine.~~ All compressor wheels are to be overspeed tested for three minutes at either 20 per cent above the alarm level speed at room temperature, or 10 per cent above alarm level speed at 45°C inlet temperature when tested in the actual housing with the corresponding pressure ratio. The overspeed test may be waived for forged wheels that are individually controlled by an approved non-destructive method; this test will not be waived for wheels of the unit to be type tested.

~~11.8~~ 12.3 Certification

~~11.8.1 The manufacturer is to adhere to a quality system designed to ensure that the designer's specifications are met, and that manufacturing is in accordance with the approved drawings.~~

~~11.8.2~~ 12.3.1 Turbochargers are to be delivered with:

~~(a) For turbochargers manufactured using mass production methods as defined in *Vol 2, Pt 2, Ch 1, 11.1 General 11.1.2*, a manufacturer's certificate that at a minimum cites the applicable type approval, including production assessment.~~

~~(b) For all other turbochargers, an LR certificate that at a minimum cites the applicable type approval and the LR Quality Scheme when applicable.~~

(a) Category B turbochargers: A manufacturer's certificate, which states the applicable Type Approval, including production assessment.

(b) Category C turbochargers: An LR certificate or LR Quality Scheme Product Certificate as applicable, which states the applicable Type Approval and LR Quality Scheme reference, if applicable.

Existing paragraph 11.8.3 has been renumbered 12.3.2.

12.3.3 The above certification and test requirements also apply to the replacement of rotating parts and casing.

12.4 Matching with engine

12.4.1 Turbochargers are to have a compressor characteristic that allows the engine on which it is installed to operate without surging during all operating conditions. For abnormal, but permissible, operation conditions, such as misfiring and sudden load reduction, no continuous surging is to occur.
Note: Surging and continuous surging are defined as follows: Surging means any phenomenon which results in a high pitch vibration of an audible level or explosion-like noise from the scavenger area of the engine. Continuous surging means that surging happens repeatedly and not only once.

12.4.2 Category C turbochargers used on propulsion engines are to be tested to ensure an adequate operating margin without surge occurring during the engine works trials as specified below. These tests may be waived if successfully tested earlier on an identical configuration of engine and turbocharger (including same nozzle rings).

(a) For trunk piston engines the following are to be performed without indication of surging:
  (i) With maximum continuous power and speed (i.e. 100 per cent), the speed is to be reduced with constant torque (fuel index) down to 90 per cent power.
  (ii) With 50 per cent power at 80 per cent speed (i.e. propeller characteristic for fixed pitch), the speed is to be reduced to 72 per cent while keeping constant torque (fuel index).

(b) For crosshead engines the surge margin is to be demonstrated by at least one of the following methods:
  (i) The engine working characteristic established at workshop testing of the engine is to be plotted into the compressor chart of the turbocharger (established in a test rig). There is to be at least a 10 per cent surge margin in the full load range, i.e. the working flow is to be at least 10 per cent above the theoretical (mass) flow at the surge limit (at no pressure fluctuations).
  (ii) Sudden fuel shut-off to at least one cylinder is not to result in continuous surging and the turbocharger(s) is(are) to stabilise at the new load within 20 seconds. For applications with more than one turbocharger the fuel is to be shut-off to the cylinders immediately upstream of each turbocharger. This test is to be performed at two different engine loads:
    - The maximum power permitted with one cylinder misfiring.
    - The engine load corresponding to a charge air pressure of about 0,6 bar (but without auxiliary blowers running).
  (iii) Sudden power reduction from 100 per cent to 50 per cent of the maximum continuous power is not to result in continuous surging and the turbocharger(s) is(are) to be stabilised at the new load within 20 seconds.

■ *Section ~~12~~ 13*
Type Testing – General

~~12.1~~ 13.1 Engines

~~12.1.1~~ 13.1.1 New engine types or developments of existing types are to be subjected to an agreed programme of type testing to complement the design appraisal and review of documentation. ~~The programme will need to include short term high power operation where applicable.~~

Existing paragraphs 12.1.2 and 12.1.3 have been renumbered 13.1.2 and 13.1.3.

~~12.1.4~~ 13.1.4 Wherever practical, type tests are to be conducted with the engine control systems operational in the approved configuration, *see Vol 2, Pt 2, Ch 1, ~~2.1 Approval process~~ 1.4 Submission requirements* and *Vol 2, Pt 2, Ch 1, ~~13.3~~ 4.3 Control engineering systems ~~13.3.2~~ 4.3.2*. Configuration management documents that satisfy the requirements of ISO 10007 or an equivalent national or international standard~~,~~ are to be reviewed at testing for validity and referenced in the type test report.

Existing paragraphs 12.1.5 has been renumbered 13.1.5.

13.1.6 A type test carried out for a particular type of engine at any place of manufacture will be accepted for all engines of the same type built by the licensee or the licensor, subject to each place of manufacture being found to meet LR requirements for conformity of production.

Existing sub-Sections 12.2 and 12.3 have been renumbered 13.2 and 13.3.

~~12.4~~ 13.4 Crankcase oil mist detection system

Existing paragraphs 12.4.1 and 12.4.2 have been renumbered 13.4.1 and 13.4.2.

13.4.3 The approval of one type of detection equipment may be used to qualify other devices having identical construction details. Proposals are to be submitted for consideration.

~~12.4.3~~ 13.4.4 Acceptance of crankcase oil mist detection equipment is at the discretion of LR based on the appraisal of plans and particulars and the test house report of the results of type testing. *See Vol 2, Pt 2, Ch 1, ~~2.2~~ 1.4 Submission requirements ~~2.2.5~~ 1.4.7*.

Volume 2, Part 9, Chapter 1
General Requirements for the Design and Construction of Electrotechnical Systems

■ *Section 1*
General requirements

1.5 Documentation required for supporting evidence

1.5.9 Evidence demonstrating the compatibility of the converter, cable and motor combinations to be used for the provision of essential services. Particular attention is to be given the suitability of the insulation systems used with respect to the convertor impulse magnitudes and voltage rise times, and their implications for partial discharge.

1.5.10 For high voltage a.c. rotating machines rated at above 3,6 kV, an inspection and test plan is required which enables the requirements of *Vol 2, Pt 9, Ch 3, 6.7 Survey and testing 6.7.7* to be assessed.

1.5.11 Where the system design intent specifies ‘darken ship’ requirements, a System Operational Concept associated with dark ship state is to be submitted and is to include operating modes and philosophy of systems/equipment in the dark ship state, including reversionary and emergency modes recognising the operational and manning philosophy for the vessel. *See also Vol 2, Pt 1, Ch 3, 3.4 System operational concept*.

1.6 Surveys

(Part only shown)
1.6.3 For electric propulsion systems, in addition to the equipment listed in *Vol 2, Pt 9, Ch 1, 1.6 Surveys 1.6.2*, the following equipment is to be surveyed by the Surveyors during manufacture and testing:

- cables, *see Vol 2, Pt 9, Ch 3, 8.1 General ~~8.1.6~~ 8.1.4*;

1.6.6 Alternative approach for product assurance;

(a) LR will be prepared to give consideration to the adoption of an approach for product assurance, utilising regular and systematic audits of an organisation’s arrangements for assuring product quality, as an alternative to the direct survey of individual items.

(b) Alternative approaches for product assurance are to be approved by LR. In order to obtain approval, the requirements of *Vol 2, Pt 1, Ch 1, 8 Quality assurance scheme for machinery* or *Ch 1, 2.4 Materials Quality Scheme of the Rules for the Manufacture, Testing and Certification of Materials, July 2017, incorporating Notice No. 1 & 2* are to be complied with. Proposals for equivalent approaches are to be submitted for consideration.

Volume 2, Part 9, Chapter 3
Electrical Power Distribution and Equipment

■ *Section 6*
Rotating machines – general requirements and motors

6.1 General requirements

6.1.4 All machines of 100 kW and over, intended for Mobility or Ship Type systems, are to be surveyed by the Surveyor during manufacture and test, *see also Vol 2, Pt 9, Ch 1, 1.6 Surveys 1.6.6*.

■ *Section 8*
Electric cables, optical fibre cables and busbar trunking systems (busways)

8.1 General

8.1.4 Surveys of cables for electric propulsion systems during manufacture and testing, *see Vol 2, Pt 9, Ch 1, 1.6 Surveys 1.6.3*, are to assess compliance with the applicable International, National or Naval Standards and the application of an acceptable quality management system, *see also Vol 2, Pt 9, Ch 1, 1.6 Surveys 1.6.6*.

Volume 2, Part 9, Chapter 6
Lighting

■ *Section 4*
Lighting systems

4.4 Emergency lighting

4.4.6 Switches are not to be installed in the final sub-circuits to emergency light fittings unless the light fittings are serving normally unmanned spaces, (e.g. storage-rooms, cold rooms, etc.), or they are normally required to be extinguished for operational reasons, e.g. for night visibility from the navigating bridge. Where switches are fitted they are to be accessible only to ship's crew and embarked personnel with provision made to ensure that the emergency lighting is energised when such spaces are manned and/or during emergency conditions. Where ‘darken ship’ requirements are specified, switches may be installed in the circuits to emergency light fittings (including transitional lighting) provided they are clearly identified.

Volume 2, Part 9, Chapter 7
Control, Alerts and Safety Systems

■ *Section 2*
Performance requirements

2.1 Performance requirements

2.1.23 Where the system design intent includes ‘darken ship’ capability, the controls and alerts are to be arranged to support safe operation in this state.

■ *Section 3*
Verification requirements

3.1 General

3.1.3 Where the system design intent includes ‘darken ship’ capability, the requirements in V*ol 3, Pt 3, Ch 5, 7.1 Equipment arrangement objective 7.1.5(c)* are to be applied.

Existing paragraph 3.1.3 has been renumbered 3.1.4.

Volume 2, Part 10, Chapter 1
Ergonomics

■ *Section 7*
Ergonomics of lighting

7.4 Location of lighting controls and outlets

7.4.4 Light switches and dimmers are to be fitted in easily accessible locations where safe and effective operation is possible.

7.5 Night vision of watch keepers

(Part only shown)
7.5.1 In order to maintain night vision and facilitate safety during hours of darkness (including 'dark ship' state, where relevant), the requirements of *Vol 2, Pt 10, Ch 1, 7.5 Night vision of watch keepers 7.5.4* to *Vol 2, Pt 10, Ch 1, 7.5 Night vision of watch keepers 7.5.10* are to be complied with.

7.5.6 During hours of darkness, and including 'dark ship' operations, it is to be possible for bridge personnel to discern equipment on the bridge so that they can move about and locate equipment.

7.5.7 The controls of dimmers are to be at the margin of visibility of the dark-adapted eye. This illumination is to be compatible with image intensifying devices.

~~7.5.7~~ 7.5.8 ~~Red or low~~ Low intensity light is to be used to maintain dark adaptation whenever necessary in areas or on items of equipment (other than the chart table) that require illumination in the operational mode. This is to include equipment in the bridge wings.

~~7.5.8~~ 7.5.9 Indirect ~~low level red or~~ low intensity lighting is to be available at deck level, especially for internal doors and staircases. ~~Provision is to be made to prevent red light from being seen from outside the ship.~~

~~7.5.9~~ 7.5.10 Instrument lighting in specified areas is to be such that duty personnel can read off displays, dials and indicators without impediment of ~~night vision~~ dark adaptation.

~~7.5.10~~ 7.5.11 Lighting ~~of~~ (including lighting of instruments, keyboards and controls) is ~~are~~ to be adjustable down to zero to preserve dark adaptation and for 'dark ship' operations, except for alarm and warning indicators, ~~and the controls of dimmers~~ which are to remain ~~readable~~ at the margin of readability of the dark-adapted eye. This illumination is to be compatible with image intensifying devices.

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